FISHERY RESEARCH

KOOTENAI RIVER WHITE STURGEON SPAWNING AND RECRUITMENT EVALUATION

ANNUAL PROGRESS REPORT
April 1, 2002 to March 31, 2003

Prepared by:

Pete Rust, Senior Fisheries Research Biologist

Vaughn L. Paragamian, Principal Fisheries Research Biologist

and

Virginia Wakkinen, Fisheries Technician

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Pete Rust
Vaughn L. Paragamian
Virginia Wakkinen

Idaho Department of Fish and Game
600 South Walnut Street
P.O. Box 25
Boise, ID 83707

To

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97283-3621

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ABSTRACT

Sampling for adult Kootenai River white sturgeon *Acipenser transmontanus* began in March 2002 and continued through April 2002. Fifty-six adult white sturgeon were captured with 3,017 hours of angling and set lining, and one additional adult sturgeon was captured while gillnetting for juveniles. Peak spring flows from Libby Dam in 2002 were nearly twice that of 2001 and the highest in over a decade due to high Libby Dam discharges resulting from high precipitation and a cold spring followed by rapid June snowmelt. As a result, Libby Dam flood control operations released up to 1,133 m^3/s (40,000 cfs). From late winter to early spring 2002, Lake Koocanusa and the Kootenai basin were still suffering from the drought conditions of 2001. Flows in the Kootenai River at Bonners Ferry during March 2002 peaked at 304 m^3/s on March 1 and dropped steadily to 167 m^3/s by March 26. Flows increased in April and peaked April 16 at 626 m^3/s before dropping to 353 m^3/s by May 1. By May 20, flows exceeded 623 m^3/s and remained high through late August. Water temperature remained relatively cold throughout most of the summer period with temperatures remaining below 13°C until July 9. Temperatures for the period ranged from 4.8 to 16.6°C (41 to 62°F) from April through September. During the week of June 24, 2002, the Seattle District of the U.S. Army Corps of Engineers scheduled a comprehensive spill test intended to measure how a range of spillway releases at Libby Dam affected the levels of total dissolved gas in the river downstream. We monitored the movements of 20 adult sturgeon from September 1, 2001 to August 31, 2002. These included fish in Kootenay Lake, British Columbia (BC) and the Kootenai River in Idaho and BC that were tagged in previous years. Six tagged adult white sturgeon were located in the spawning reach during June. Sampling with artificial substrate mats began May 6 and ended July 16, 2002. We sampled 1,805 mat d (a mat d is one 24 h set) during white sturgeon spawning. A total of 296 white sturgeon eggs were collected from June 3 through July 2, 2002. A single mat on May 31 held 157 eggs, comprising 53 percent of the total collection, and 85 percent (252) of these eggs were viable. Seven geographic areas were sampled, but all eggs were collected from the Shortys Island reach (RKM 229.6 to 231.5). Eight spawning events were identified from May 31 through June 30, 2002. An experimental release of 38,400 white sturgeon larvae from the Kootenai Tribe of Idaho Hatchery began on June 18. The flow on June 18, 2002 was nearly double the 10-year average, none of the hatchery larvae were caught after their release, and no wild sturgeon larvae were caught during our ½ m and D-ring sampling efforts. We expended a total of 328 h of gillnetting effort and captured 286 juvenile white sturgeon from July 16 through September 24, 2002. Only one of the juveniles captured was wild, while the remainder were hatchery fish.

Authors:

Pete Rust
Senior Fisheries Research Biologist

Vaughn L. Paragamian
Principal Fisheries Research Biologist

Virginia Wakkinen
Senior Fisheries Technician

OBJECTIVE

1. Determine environmental requirements for adequate spawning and recruitment of white sturgeon *Acipenser transmontanus*.

STUDY SITE

The Kootenai River originates in Kootenay National Park, British Columbia (BC). The river flows south into Montana and turns northwest at Jennings, near the site of Libby Dam, at river kilometer (RKM) 352.4 (Figure 1). Kootenai Falls, 42 km (26 mi) below Libby Dam, is thought by some to be an impassable barrier to sturgeon. As the river flows through the northeast corner of Idaho, there is a gradient transition at Bonners Ferry. Upriver from Bonners Ferry, the channel has an average gradient of 0.6 m/km (3.15 ft/mi), and the velocities are often higher than 0.8 m/s (2.6 ft/s). Downstream from Bonners Ferry, the river slows to velocities typically less than 0.4 m/s (1.3 ft/s). Here, the average gradient is 0.02 m/km (0.1 ft/mi), and the channel deepens as the river meanders north through the Kootenai River Valley. The river returns to BC at RKM 170 and enters the South Arm of Kootenay Lake at RKM 120. The river leaves the lake through the West Arm of Kootenay Lake to its confluence with the Columbia River at Castlegar, BC. A natural barrier at Bonnington Falls (now a series of four dams) has isolated the Kootenai River white sturgeon from other populations in the Columbia River basin for approximately 10,000 years (Northcote 1973). The basin drains an area of 49,987 km^2 (19,300 mi^2) (Bonde and Bush 1975). Regulation of the Kootenai River with Libby Dam changed the natural hydrograph of the river. Post-Libby Dam flows during spring were reduced by about a third, and flows during winter are now three to four times higher (Figure 2). Since 1991, Libby Dam has released spring flows intended to benefit white sturgeon spawning (Figure 2).

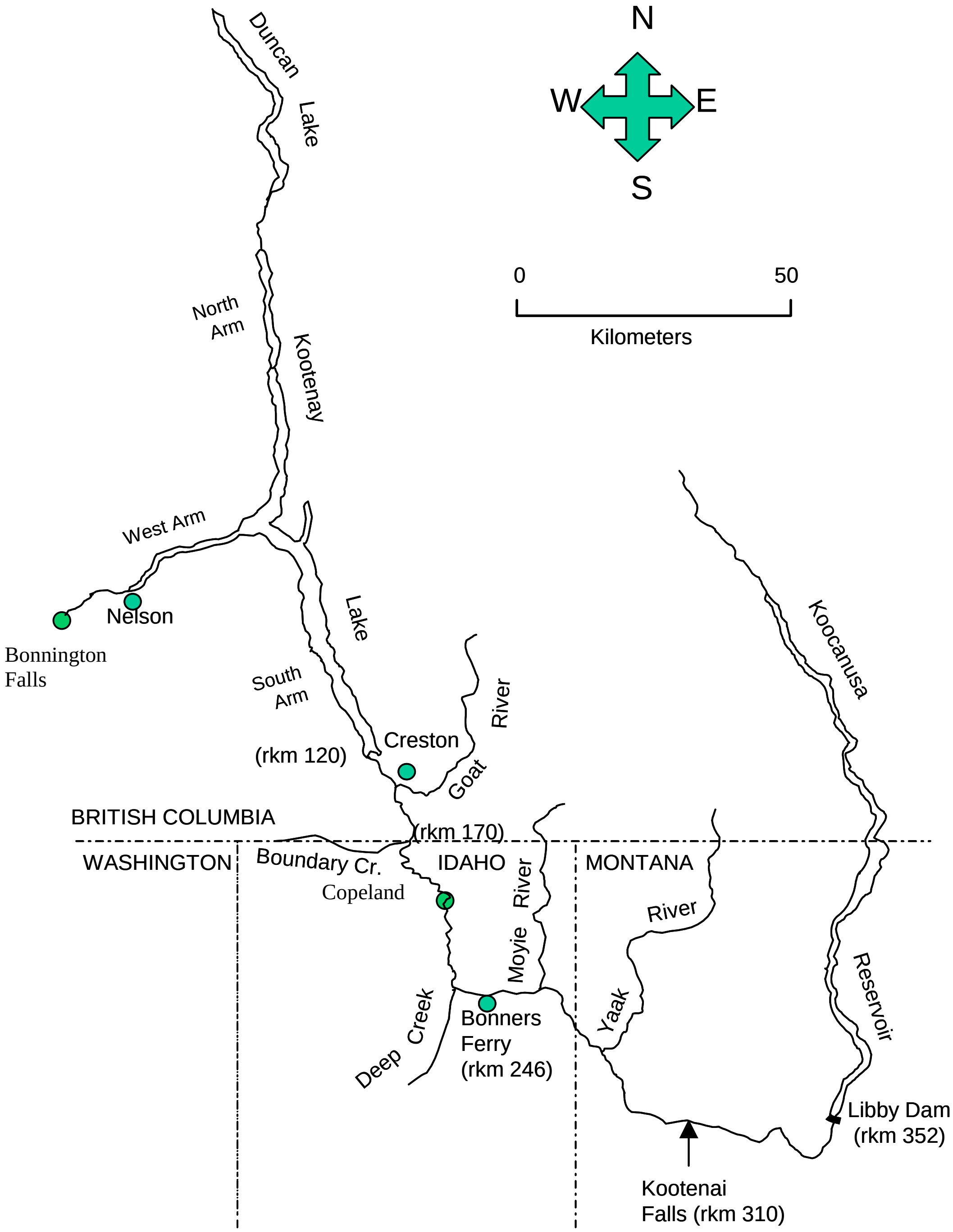


Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (RKM) and are indicated at important access points.

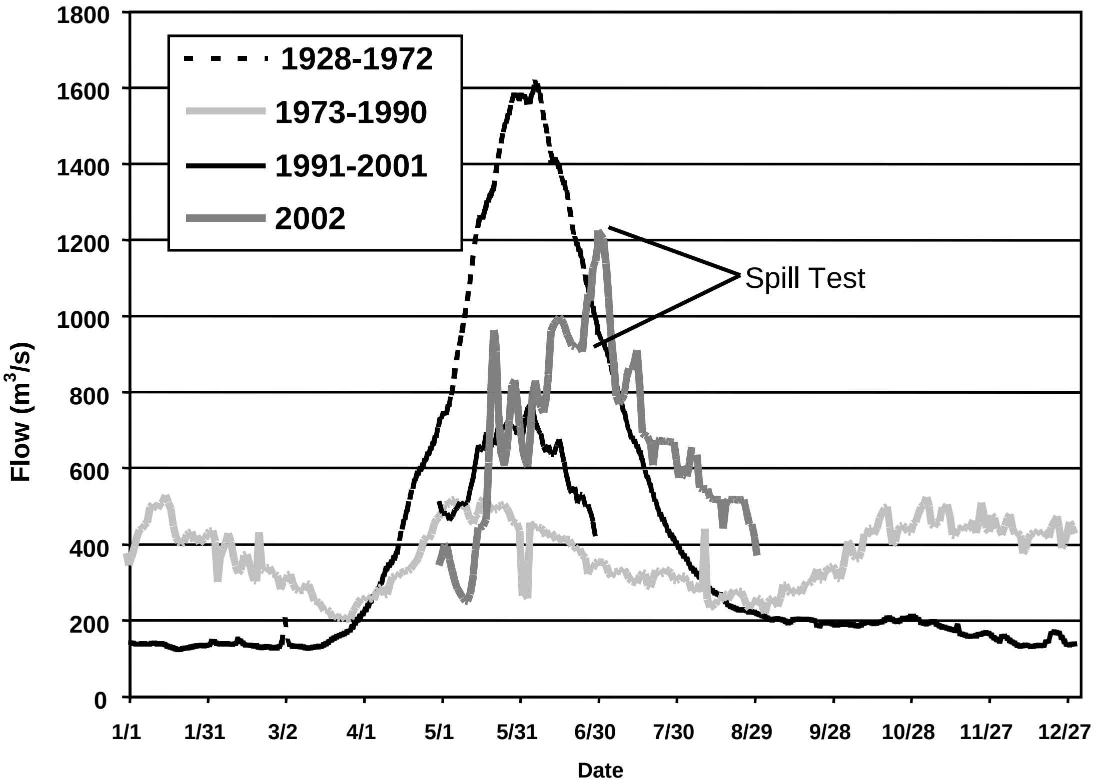


Figure 2. Mean daily flow patterns in the Kootenai River at Bonners Ferry, Idaho from 1928-1972 (pre-Libby Dam), 1973-1990 (post-Libby Dam), 1991-2001 (post-Libby Dam with augmented flows, May 1 through June 30), and 2002 (May 1 through August 31).

METHODS

Discharge, Water Temperature, and Secchi Measurements

Kootenai River discharge and water temperature data at Bonners Ferry and discharge from Libby Dam were obtained from the U.S. Army Corps of Engineers (USACE). Because of high spring inflow into Lake Koocanusa and subsequent high Libby Dam discharges, river conditions in spring 2002 resembled a pre-Libby Dam hydrograph more closely than in recent history (Figures 2 and 3). Sturgeon flows were provided and, due to the flood control operations, exceeded the USFWS request in 2002. *See http://www.nwd-wc.usace.army.mil/sor/2002/2002-U2.pdf.*

Secchi disc measurements were made from May 31 through July 11 during mat sampling to provide a measure of turbidity during the spawning season. Measurements were made at RKM 229.5, 240.0, and 244.5 and averaged daily.

Adult White Sturgeon Sampling

Adult white sturgeon were captured with rod and reel or set lines from March 4, 2002 to April 12, 2002, following the methods of Paragamian et al. (1996). Adult white sturgeon expected to spawn in 2002 were tagged with a depth sensitive radio transmitter and a sonic tag and monitored to determine movements during the spawning season (Paragamian et al. 1996).

Adult White Sturgeon Telemetry

Boat Telemetry

Movements and migration of adult white sturgeon, fitted with both sonic and radio transmitters, were monitored monthly by boat from the Kootenai River at Bonners Ferry to the river's delta at Kootenay Lake. Radio transmitters were manufactured by Advanced Telemetry Systems (ATS) and were model 2130. Acoustic transmitters were manufactured by Sonotronics and were model CT-82-3-AA. The main objective was to locate late vitellogenic females and reproductive males migrating upstream to staging and spawning reaches. Each transmitter location was recorded to the nearest 0.1 RKM (0.061 mi). Effort to monitor sturgeon movement and activity varied with season. Less effort was provided during winter months when most fish moved less frequently than in spring and autumn. More frequent monitoring occurred during the prespawning and spawning seasons to follow the increased movement of tagged fish. Reaches above Copeland, Idaho (Figure 1) were monitored more intensively than downriver or Kootenay Lake, especially during the prespawning and spawning periods when mature sturgeon moved upstream.

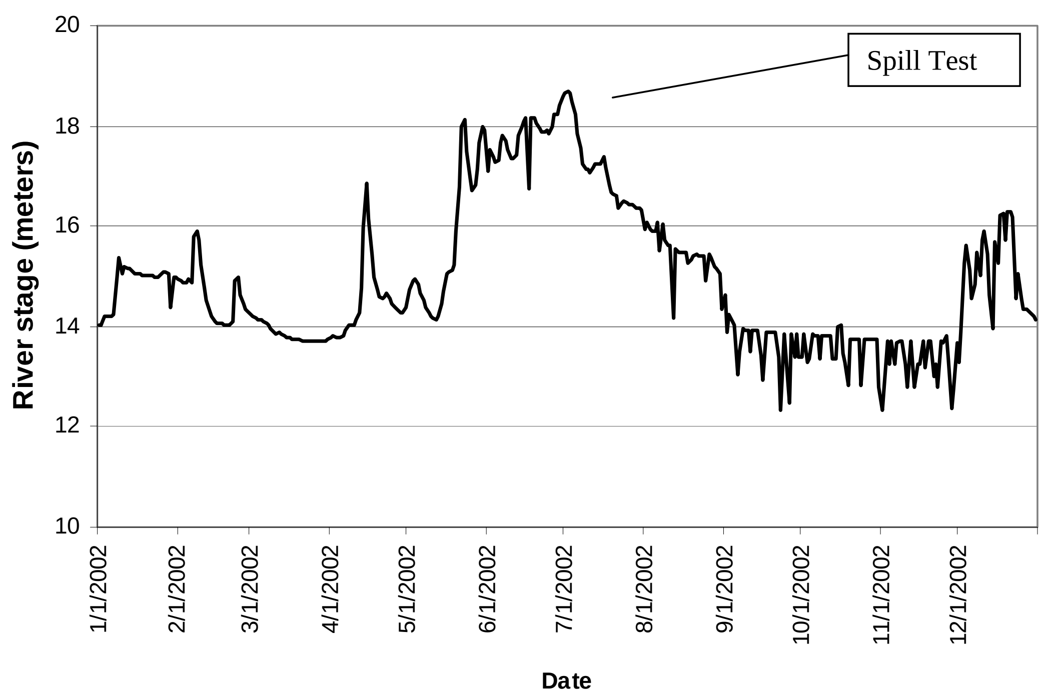


Figure 3. Mean daily river stage (meters) in 2002 for Kootenai River at Bonners Ferry, Idaho.

Fixed Receiver Telemetry

Fixed location receivers provided us with the opportunity to detect movements into specific locations at documented times of the day including the evening through morning hours. Three fixed receivers were stationed between RKM 230.5 and 244.5 (see Appendices G-N). Site 1 was situated furthest downriver at Flemming Creek (RKM 224.5). This downriver position was selected to detect and verify fish movements into the Flemming Creek area (RKM 224.0 to 225.0) in conjunction with the BioSonic dual beam echo sounder sonar station. Site 2 was located at the Kootenai National Wildlife Refuge (RKM 237.5). Site 3 was located just upriver from Ambush Rock (RKM 244.5) on the south side of the Kootenai River at the end of a straight reach. This upriver location was chosen in 1999 in an attempt to detect fish movements above Ambush Rock (RKM 244.4), eliminate background noise problems experienced at previous sites on the north side of the river, and avoid vandalism that occurred at the previous south side sites in 1997 and 1998. This site is also the lower reach of river with gravel and cobble substrate.

Each fixed receiver station consisted of a scanning receiver (ATS model R2100), data logger (ATS model DCCII), 3-element Yagi antenna, and 12-volt deep-cycle battery to operate the system. Antennas were mounted on 1.8 m (6 ft) metal fence posts horizontal to the river and affording a clear 180-degree view of the river. Selected sites were all on straight reaches to facilitate reception of the radio frequencies of potential male and female spawners programmed into the receivers. Data loggers were set to record only those frequencies matching tagged white sturgeon. Each receiver was upgraded to conform to the depth sensitive transmitters to count signals per minute in order to detect depth. A pattern-matching option was selected to verify signals. A test radio tag was used to verify detection range and strength at each site.

Fixed Wing Telemetry

Two loop antennas were mounted on the wing struts of a Cessna 182 for fixed wing aerial telemetry. Flights followed a route downriver from Bonners Ferry to Kootenay Lake at an altitude of 152 to 305 m (500 to 1,000 ft) above the river and speeds of 60 to 80 knots (69 to 92 mph). Up to 13 preset radio frequencies of potential spawners were cycled through an ATS model R2100 scanning receiver and deleted as fish were detected. The frequency cycling rate was two to four seconds to facilitate maximum numbers of fish cycled without sacrificing detection range. Locations were made to the nearest 0.1 RKM.

Depth Sensitive Radio Telemetry

Depth sensitive radio transmitters (ATS model 2130) were attached to four late vitellogenic females to determine the vertical location of white sturgeon in the water column during the prespawn and spawning seasons. The purposes of this research were threefold. First, we wanted to establish the relation of fish location to current velocities before, during, and after the spawning period. Second, we wanted to determine at what depth, with respect to the water column and with respect to the available depth, sturgeon are spawning. Finally, we wanted to more precisely determine specific behaviors before, during, and after the spawning season and determine the feasibility of and most suitable locations for creating spawning structures or some type of spawning habitat enhancement.

Depth sensitive radio transmitters are pressure responsive, and the depth of the tag can be determined by the pulse frequency, with the frequency increasing with increasing depth. A stopwatch was used to determine the number of seconds for 10 pulses (period). This period was later converted to milliseconds. The average of three readings was used to determine depth in the water column. The average of the three pulses was entered into a regression equation, and the estimated transmitter depth was calculated. To provide more precise depth estimates for each fish, a regression equation was prepared for each radio, prior to attachment, by submersing the radio to known depths and counting pulses. The river depth at the fish location was determined using a depth finder and was recorded to the nearest foot (later converted to metric). Contrary to 2001 when several individuals were tracked during the spawning season, in 2002 we chose one individual fish and followed it exclusively throughout the study. Each day was divided into three, eight-hour time blocks (0000-0800, 0800-1600, 1600-2400), and sampling days and sampling blocks were randomized. Individual locations and depth in the water column were recorded approximately three times per hour for each eight-hour sampling block. We will use Chi-square analysis to detect any differences in night and day locations and to evaluate differences above and below the middle water column depth.

Adult Spawner Stock Estimate by Dual Beam Sonar

We used a fixed location dual beam sonar unit in an experimental study to help estimate the number of adults in the spawning stock. A BioSonic DT6000 surface unit (receiver) was accompanied by a DT 200 kHz 6x15° elliptical transducer, and the information was transferred to a Dell Inspiron 3800 computer control unit that had an 80 GB external hard disk drive. The transducer was attached to a 152 m DT digital signal cable that was connected to the receiver. The transducer was mounted on an adjustable tripod that was located underwater near the west riverbank at Flemming Creek (RKM 225.2). The 6X15° beam was adjusted to transmit underwater across the Kootenai River to a hard wall of bedrock at the east river bank, approximately 75 m. A fixed location radio receiver was coordinated with the dual beam sonar to help verify the effectiveness of the sonar. As radio-tagged white sturgeon passed the fixed location receiver, they also passed within the beam of the sonar. The coordinated effort of the dual beam sonar and the fixed location receiver provided us with two pieces of information: 1) fish detection ability and efficiency of the radio and sonic tagged white sturgeon that passed through the beam (ratio of radio-tagged sturgeon that were recorded to those not recorded), and 2) it helped us verify that the object was a sturgeon so that the target strength could be distinguished from non-sturgeon targets (e.g. logs, muskrats, etc.). With this information, we believed we would be able to estimate the total number of mature sturgeon moving into the spawning reach. This estimate would be based on the total number of sturgeon moving into the reach multiplied by the proportion of mature adults in the spawning reach expected to spawn (based on gonad development determined from surgical procedures).

Artificial Substrate Mat Sampling

Artificial substrate mats were used to document white sturgeon spawning (McCabe and Beckman 1990). Post-Libby Dam sturgeon spawning locations in the Kootenai River have been well documented (Paragamian et al. 2002), and mats were placed within these spawning areas in seven geographic areas. The length of the spawning reach was marked along the shoreline with flag material at each 0.1 km increments.

The number of mats placed within each geographic area was based on the size of the area and the historic egg catch. An average of 48 mats (range 15 to 53) were deployed daily and mat deployment location was recorded to the nearest 0.1 river km. Fewer mats were used in 2002 so more time could be allocated to telemetry and other studies. All eggs were removed from the mats, stored in labeled vials containing 10% formalin or 70% ethyl alcohol solution, and brought back to the laboratory. In the lab, eggs were first determined to be viable or dead. If the egg was viable, the spawning date was estimated according to Beer (1981).

Prejuvenile Sturgeon Sampling

Young sturgeon were classified as prejuveniles when they had yet to develop ossified elements in the fins, flattening of the ventral surface, and development of a toothless highly protrusible mouth. Based on the classification of Richmond and Kynard (1995), prejuveniles were further classified as hatchlings (<1 d old), embryos (1 to 8 d old), and larvae (9 d to development of juvenile physical characteristics and behaviors).

Prejuvenile white sturgeon sampling in the Kootenai River was conducted using ½ m nets at midwater column depths and at the surface and D-ring nets at the bottom of the Kootenai River. Due to the high water velocities and large amounts of woody debris in the water in 2002, no active tows were conducted. All nets were fished passively with the boat held stationary. Lead weights ranging from 2.7 to 9.1 kg (6 to 20 lbs) were attached to midcolumn and bottom nets in order to reach desired depths. Flow meters attached to the mouth of each net measured current velocity, which when combined with total sampling time and respective net mouth dimensions gave the total volume of water sampled. Sampling took place during daylight hours at various times of day in 10 predetermined locations between RKM 220.0 and 244.5. Sampling locations were selected based on river morphology (areas where the river is narrow, where current is directed toward a bank or structure, or where sampling effort is thought to be maximized). Sampling day and location were randomized (with replacement) with equal probabilities of sampling any particular location on any given day.

Experimental Release of Hatchery White Sturgeon Prejuveniles

Hatchery reared white sturgeon prejuveniles and embryos (4 to 9 d old) from the Kootenai Tribe of Idaho (KTOI) hatchery were released into the Kootenai River at Hemlock Bar (RKM 262.5) to help resolve an “egg to juvenile survival bottleneck” hypothesis. Subsequent recruitment to gillnets or trawls in two or three years will test whether releasing hatchery white sturgeon embryos over gravel-cobble leads to increased survival. Sampling to determine the effectiveness of our gear was conducted during the first release only (June 18), approximately 200 meters downstream of the release site. All sampling was with ½ m and D-ring nets; sampling started at 2045 and continued until 2130.

Juvenile White Sturgeon Sampling

Gillnetting

Five sizes of weighted multifilament gillnets with 3.8, 5.1, 7.6, 10.2, and 15.2 cm (1.5, 2, 3, 4, and 6-inch) stretch mesh were used to sample juvenile and young-of-the-year (YOY) sturgeon (Paragamian et al. 1996; Fredericks and Fleck 1996) from July to September 2002. Gillnet sampling was conducted at one of 12 predetermined index sites located between RKM 192.0 and 230.5. Gillnets were set during the day and checked every hour. All juvenile sturgeon were processed by methods cited in Paragamian et al. (1996).

Seventy-five percent of the sampling was conducted at five locations (index sites) thought to be prime juvenile sturgeon habitat. The remaining 25 percent of the effort was directed toward seven locations thought to be marginal juvenile habitat. Site selection was randomized with replacement. This sampling regime was designed to begin evaluating the carrying capacity and optimal juvenile stocking rates by the KTOI. If juvenile sturgeon densities begin increasing in marginal habitat, one assumption would be that carrying capacity has been reached in prime habitats and stocking rates or locations should be adjusted.

Beam Trawling

Benthic trawls have been an alternative method of qualifying and quantifying juvenile sturgeon presence and abundance. Two types of benthic trawls have been used in the Kootenai River to sample for juvenile sturgeon, a beam trawl with a mouth measuring 51 by 201 cm (20 by 79 in) and an otter trawl with a mouth measuring 61 by 213 cm (24 by 84 in). Trawls were towed downstream at speeds that would slightly exceed the river current yet still allow the net to fish along the bottom of the river. Sampling was performed during daylight hours in 2002. Benthic trawling provided the opportunity to sample the bottom of the river with gear that would be selective for age-0 sturgeon and juvenile sturgeon that were not yet recruited to gillnets.

RESULTS

<u>Discharge, Water Temperature, and Secchi Measurements</u>

Peak spring flows from Libby Dam in 2002 were nearly twice that of 2001 and the highest in over a decade due to high Libby Dam discharges resulting from high precipitation and a cold spring followed by rapid June snowmelt. As a result, Libby Dam flood control operations released up to 1133 m^3/s (40,000 cfs) (Figures 2 and 3). Flows in the Kootenai River at Bonners Ferry during March peaked at 304 m^3/s on March 1 and dropped steadily to 167 m^3/s by March 26. Flows increased in April and peaked April 16 at 626 m^3/s before dropping to 353 m^3/s by May 1. By May 20, flows exceeded 623 m^3/s and remained high through late August at Bonners Ferry, Idaho. Water temperature remained below 13°C until July 9. Temperatures for the period ranged from 4.8 to 16.6°C (41 to 62°F) from April through September.

Secchi measurements from May 31 through July 11 averaged 1.22 m, N = 46, SD = 0.35 m (4.02 ft, SD = 1.15 ft), and ranged from 0.87 m (2.86 ft) to 1.58 m (5.17 ft) (Figure 4).

During the week of June 24, 2002, the Seattle District of the USACE scheduled a comprehensive test intended to measure how a range of spillway releases at Libby Dam affected the levels of total dissolved gas in the river downstream. The spill test design allowed comprehensive measurement of how total dissolved gas levels change with time and distance from Libby Dam to just downstream of Kootenai Falls at RKM 310, a distance of about 42 river kilometers (USACE 2002). One additional station monitored dissolved gas levels at Porthill, Idaho, where the Kootenai River enters British Columbia, Canada. The spill test schedule called for spillway flows to start at about 57 cubic meters per second (m^3/s) on the morning of June 24 and gradually increase in increments of 28 m^3/s to about 283 m^3/s by the end of the test on the evening of June 27. Dissolved gas data obtained from one sensor located about 1000 m downstream of the dam on the spillway side of the river revealed that the 170 m^3/s spill event caused dissolved gas levels to increase to levels that exceeded an average of 120% saturation over the 3-hour spill event. The spill test protocols established that exceeding an average dissolved gas level of 120% over any 3-hour spill interval would stop the spill test. Since both fish monitoring and dissolved gas cut-off thresholds had been exceeded, the spill test protocols called for cessation of the test. However, the flood control operations required continued use of the spillway to slow reservoir refill. Thereafter, the dam was operated at maximum powerhouse discharge with spillway flows as necessary to slow the refill of Lake Koocanusa and forestall the likelihood of even larger spillway flows in the coming weeks (USACE 2002).

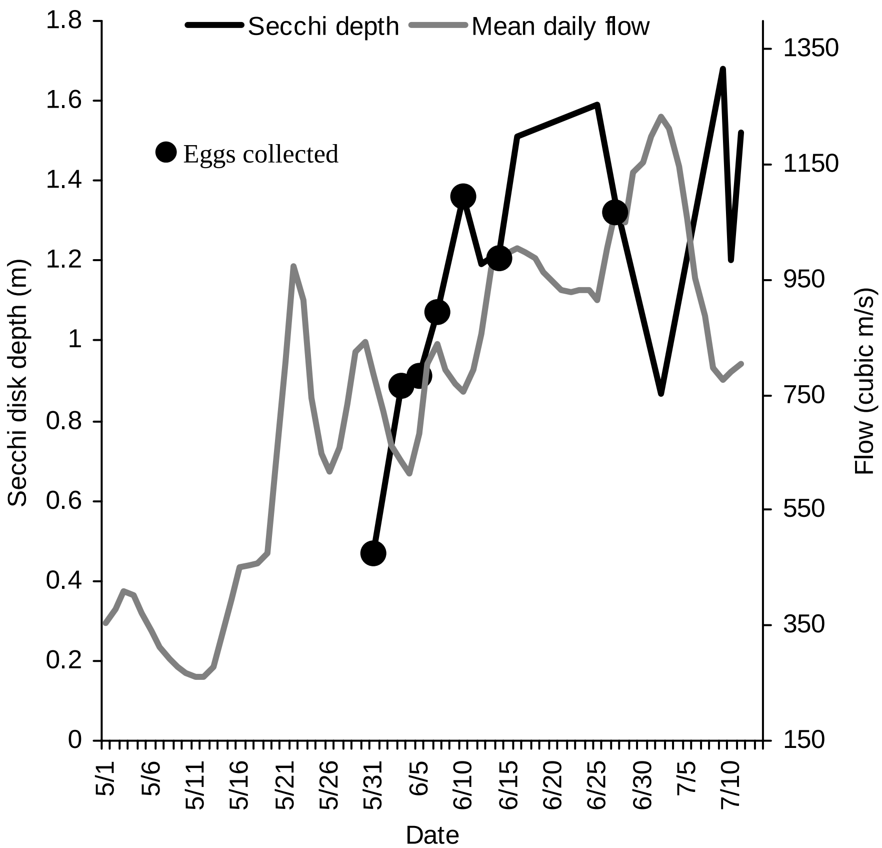


Figure 4. Secchi disk depth (m) and flow (m^3/s) in the Kootenai River near Bonners Ferry from May 31 to July 11, 2002.

Adult White Sturgeon Sampling

Fifty-six adult white sturgeon were captured with setlines, angling, and gillnets in 2002. Fifty-five of the adult white sturgeon were captured with 3,017 hours of angling and setlining effort between March 4 and April 12, 2002 (Table 1). Forty-six (82%) of the adult white sturgeon were captured with setlines, and catch per unit effort (CPUE) for angling and setline gear was

0.041 and 0.016 fish/rod or setline h, respectively. One other adult sturgeon was captured incidentally in a small-mesh gillnet; however, no juveniles were captured in the adult sets.

Forty-three (77%) of the 56 adult sturgeon were recaptures from previous years (Table 1). The Idaho Department of Fish and Game (IDFG) performed 16 biopsies on adult sturgeon during 2002 to determine sexual maturity and stage of ovaries and testes (Appendix 1). Sonic and depth sensitive radio transmitters were attached to four reproductively mature females and five mature male white sturgeon in 2002.

Table 1. Sampling effort and number of adult and juvenile white sturgeon caught by the Idaho Department of Fish and Game in the Kootenai River, Idaho, March 4, 2002 to September 24, 2002.

	Hours of effort	**Number of juvenile sturgeon caught**	**Number of adult sturgeon caught (No. of recaptures)**	**Juvenile CPUE (fish/h)**	**Adult CPUE (fish/h)**
Gillnet	328.3	286	1(1)	0.871	0.0030
Beam Trawl	2.7	1	0	0.370	0
Angling	197.0	1	8(7)	0.005	0.0406
Setline	2,819.5	0	47(35)	0	0.0160
Total		**288**	**56(43)**		

Adult Spawner Stock Estimate by Dual Beam Sonar

The dual beam echo sounder was initiated March 29, 2002 and ran, with occasional short breaks, until July 19, 2002. Breaks in activity were due to extremely high flows creating technical and logistical problems, and mechanical failures (battery failure, software problems, and computer hardware problems). Flows increased rapidly from April 3 (4,506 cfs or 127 m^3/s) through April 15, when they peaked at 1057 m^3/s (37,342 cfs). This rapid increase in flows generated large files due to high volumes of small and large debris and turbulent water that the storage setup could not accommodate. Later high flow periods also generated large files that required frequent downloading of data or a resulting system shutdown when storage capacities were exceeded. High flows and debris loads also affected the quality of the echogram due to periods when the pathway in front of the transducer was partially blocked. This affected the quality of the signal emitted from the transducer and reduced the area of the river that was sampled.

In spite of the technical and logistical problems encountered, the dual beam echo sounder station successfully detected sturgeon passing through the beam. Several fish of varying sizes were detected on many different occasions. The fixed receiver station located at the site and boat telemetry efforts in the area verified many of the fish identified. Some of the detected fish were suspected spawners, including females numbered 996 and 1581 and males numbered 504 and 993 (Table 2).

Adult White Sturgeon Telemetry

We monitored the movements of 23 adult sturgeon from September 1, 2001 to August 31, 2002 (Figure 5; Table 2; Appendices B, C, D, and E). These included fish in Kootenay Lake, BC and the Kootenai River in Idaho and BC. The total included 13 females, nine males, and one fish of undetermined sex. Fifteen of the 23 adult sturgeon were monitored in the Kootenai River (Table 2). Of these 15, 12 (six females and six males) moved to the spawning reach from staging or overwintering areas (Table 2, Appendices B, C, D, and E). Six fish (female fish numbered 990, 996, and 2227 and males 43, 87, and 993) were located in the spawning reach (RKM 228.0 to 246.0) during times when spawning was estimated to have occurred (Table 3). These six fish and six more (females numbered 812, 990, 996, 1579, 1581, and 2227 and males 43, 87, 145, 504, 880, and 993) are thought to have spawned (Table 2, “expected” and “suspected spawners”) based on their ovary development at capture and/or their movements during the spawning season. Female number 812 was thought to have spawned in 2001 (based on movement data). She swam upriver (above RKM 240.0) from the Rock Creek area (RKM 215.0) several times from mid May through June 2001. She dropped below RKM 225.0, where she overwintered, by mid August 2001. By late May 2002, she was back upstream of RKM 240.0. She remained upstream (above RKM 234.0) until the end of June 2002, dropping below RKM 225.0 by June 28, 2002.

Boat Telemetry

Boat telemetry for sturgeon locations was carried out from September 1, 2001 through August 31, 2002 (Figure 5). One hundred nine trips were made for a total of 309.0 h, during which 315 white sturgeon locations were recorded. Figure 5 indicates more than 120 hours of effort in May and June were spent doing sturgeon telemetry during spawning season.

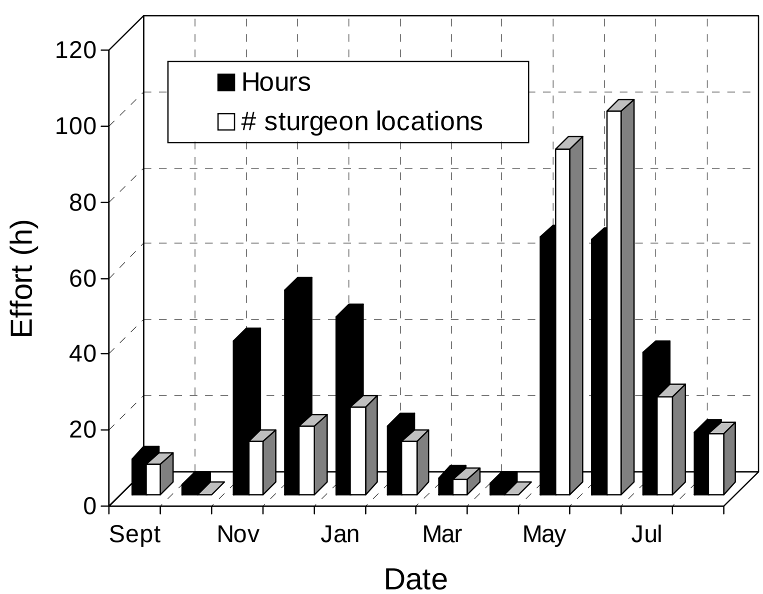


Figure 5. Telemetry effort (hours) and number of times white sturgeon were located monthly from September 1, 2001 to August 31, 2002, Kootenai River, Idaho.

Fixed Receiver Telemetry

Fixed site 1 (RKM 224.5) logged data April 4 through July 16. Site 2 (RKM 237.5) operated April 29 through May 20. Site 3 (RKM 244.5) collected data May 6 through July 9. These dates corresponded to the period of upriver movements of spawning fish as noted by current boat, aerial, and fixed station telemetry. Site 1 was operated longer to coincide with the period of activity at the dual beam echo sounder station. The only locations discussed in our analysis are those verified by boat or aerial telemetry or those occurring at more than one fixed station. The 3-element Yagi antennas detected the movements of 11 fish past one or more of the three fixed stations. This included six females (numbers 812, 990, 996, 1579, 1581, and 2227) and five males (numbers 87, 145, 504, 880, and 993).

Table 2. Upriver locations of white sturgeon monitored in the Kootenai River from March 1, 2002 through August 31, 2002 (some fish moved out of Kootenay Lake, BC).

Fish #			Tagging location	Date	Highest RKM (date)		Last date located above
Male	Unknown	Female	(RKM)	tagged	120-225	>225	RKM 225
43[a,b]		—	215.0	3/6/02	—	243.0(6/18)	6/19
87[a,b,c]		—	205.0	4/19/01[d]		234.1(6/7)	6/11
145[a,b,c]		—	215.7	3/21/02	—	244.5(6/21-7/4)	7/18
262[c]		—	205.0	4/10/01[d,e]		—	—
—		284[c]	215.5	3/14/01[d,e]		—	—
407		--	215.6	3/6/96	—	230.5(7/9)[f,g]	—
504[a,b]		—	204.5	4/15/02	—	240.2(6/21) [h]	
—		526	205.0	3/1/99 [d,e]		—	—
694[c]		—	207.0	4/9/01 [e,f]		—	—
—		812[b,c,i]	214.6	4/23/01[d]		245.6(5/30)	7/31
—	859	—	215.0	3/6/02	218.0(7/3)	—	--
880[a,b,c]		—	215.0	3/13/02	—	245.0(5/28)	7/18
—		912	215.5	3/29/00	222.0(7/9)j	—	—
—		925	208.0	4/13/00[e,,j]		—	—
—		931	122.5	10/4/00[e,,j]		—	—
—		958[c]	215.1	3/15/01[e,,j]		—	—
—		966[c]	225.0	5/4/01[e,j]		—	—
—		990[a,b]	215.7	3/7/02	—	244.5(6/3-8,14)	7/31
993[a,b,c]		—	215.0	3/13/02	—	244.5(5/15-16)	8/14
—		996[a,b,c]	215.7	4/9/02	—	244.5(5/30-31; 6/8)	6/13
—		1579[a,b,c]	215.6	4/10/02	—	244.5(6/7-8,18,23)	6/26
—		1581[a,b,c]	215.6	4/12/02	—	234.4(6/19)	6/22
—		2227[a,b,c]	215.8	4/23/02	—	244.5(6/10)	6/17
n = 9	n = 1	n = 13			Combined (n = 23)		
n = 6	n = 0	n = 6			Suspected Spawners (n = 12)		
n = 3	n = 1	n = 7			Non-spawners (n = 11)		

[a] These fish were expected spawners (assessed by their <u>development</u> in 2002).
[b] These fish were suspected spawners (determined by their <u>movements</u> in 2002).
[c] These fish were tagged with depth tags (N = 14 active, n = 6 male, n = 8 female).
[d] These fish overwintered in this section.
[e] These fish made no upriver movements out of Kootenay Lake in 2002.
[f] These fish had only one location from 3/1/02 through 8/31/02.
[g] Probably a shed tag.
[h] These fish never dropped below river kilometer 225.
[i] This fish was thought to have spawned in 2001 (based on movements) but made movements again in 2002 that suggested the spawn year was actually 2002.
[j] These fish overwintered below RKM 120.

Table 3. White sturgeon adults tracked to sections of the Kootenai River, Idaho where sturgeon eggs were collected, 2002 (eggs were staged to back calculate spawning date)

Location	Spawning date[a]	Fish number	
		Males	Females
Lower Shortys Island (RKM 227-229.5	None	None	None
Middle Shortys Island (RKM 229.6-231.5)	May 31, June 2, June 4, June 6, June 7, June 10, June 18, June 30	43, 87, 993	990, 996, 2227
Wildlife Refuge (RKM 234.0-240.0)	None	None	None
Town (>240.0)	None	None	None

[a] This assumes that eggs were spawned in the same river reach where they were collected.

Eight fish were detected at the upriver station (site 3 at Ambush Rock, RKM 244.5). This included five females (812, 990, 996, 1579, and 2227) and three males (145, 504, and 880). Ten fish were detected at site 1 (RKM 224.5), including four males (87, 145, 880, and 993) and six females (812, 990, 996, 1579, 1581, and 2227). At least four of these fish were also detected by the echo sounder.

Fixed Wing Telemetry

Fixed wing flights occurred from September 7, 2001 through August 16, 2002. Many flights occurred in conjunction with tracking flights for tagged bull trout *Salvelinus confluentus* and rainbow trout *Oncorhynchus mykiss* (Walters *In Progress*). Four flights were made searching for white sturgeon from Bonners Ferry to Kootenay Lake. In approximately 10.8 hours of flying concentrated on sturgeon, 46 (48% of the sturgeon search for) sturgeon locations were made. Sixteen different fish were located. These included 11 expected spawners (six females numbered 812, 990, 996, 1579, 1581, and 2227, and five males numbered 87, 145, 504, 880, and 993). The majority of the flying occurred from Bonners Ferry (RKM 245.0) to the Canadian border (170.0) but also down to the Kootenai River Delta and South Arm (RKM 106.0 to 122.0)

Depth Sensitive Radio Telemetry

Female number 2227 was selected for depth sensitive telemetry. She was captured May 5 in a setline at RKM 245.5. Telemetry and data collection began May 12 at Rock Creek (a known staging area) as water temperatures increased to 10°C and other telemetered white sturgeon became active. Telemetry continued from the prespawning period through the postspawning migration back to Kootenay Lake (June 17). Telemetry contacts were made approximately three times per hour for the duration of each 8-hour period, and depth preference (vertical movement) and spatial movement (horizontal movement) data were both collected. Two hundred seventeen radio contacts were made from May 15 through June 17. Depth use by this individual sturgeon ranged from 3.3 to 19.8 meters (mean 8.8, SD 2.2, SE 0.030). Eighty-eight percent of the contacts were made within the bottom one-third of the water column, and 65 percent of the contacts were made within three meters of the bottom (Appendix F). Additionally, the fish was observed in the upper one-half of the water column only four percent of the time.

Although female number 2227 spent most of her time near the bottom of the Kootenai River, we did document vertical movement within the water column. The smallest amount of vertical movement during the study occurred on May 30 when 17 contacts were made at depths ranging from 6.5 to 7.6 meters (mean 7.0, SD 0.29, SE 0.071). The largest amount of vertical movement occurred on June 17 when the fish ranged in depth from 5.9 to 19.8 meters (mean 10.6, SD 5.2, SE 1.660). During this period, there was extensive horizontal movement also, and the fish was moving steadily downstream (and through the BioSonic sonar beam) for the entire period (near RKM 224.5). It is the senior author's opinion that on this date, this individual was in a postspawn condition and was migrating back to Kootenay Lake. One week after this latest observation, the fish could not be located by boat telemetry in the river, and two weeks after the latest observation (July 1), the fish was found by fixed wing telemetry in Kootenay Lake, a movement of over 100 kilometers in less than two weeks.

A detailed analysis of this individual's movements and behavioral patterns was recorded by collecting global positioning systems (GPS) data in conjunction with the depth sensitive data. Data were collected at 20-minute intervals throughout each sampling period. Our results suggest that sturgeon movements can range from less than a few meters to several kilometers during an eight-hour sampling period. Little data exist to determine if movement extent or patterns are different during high or low-light periods. Appendix G gives an overview of the study reach from the staging areas upstream to the spawning reach, and movement patterns throughout the study period are illustrated in Appendices H through N.

Artificial Substrate Mat Sampling

We sampled 43,315 h or 1,805 mat d (a mat day is one 24 h set) in the Kootenai River during white sturgeon spawning in 2002 (Table 4). Sampling with mats began May 6 and ended July 16, 2002. Two hundred ninety-six sturgeon eggs were collected (Figure 6). A single mat on May 31 held 157 eggs comprising 53% of the total collection.

Seven geographic locations were sampled, but all of the eggs were collected from the Middle Shortys reach (RKM 229.6 to 231.5) with 627 mat d effort. Depth of artificial substrate mat placement ranged from 1.5 to 25.3 m (5.0 to 80.0 ft) for all mats. Mats that collected eggs ranged from 11.0 to 15.5 m (36 to 51 ft) in depth, averaging 13.2 m (43 ft) (Table 4). Near surface velocities (0.2 depth) at 14 egg collection sites ranged from 0.17 to 0.75 m/s (0.5 to 2.5 ft/s) and averaged 0.44 m/s (1.4 f/s). Velocities near the river substrate (0.8 depth) at the egg collection sites ranged from 0.13 to 0.84 m/s (0.4 to 2.8 ft/s) and averaged 0.45 m/s (1.5 ft/s). Mean column velocity at egg collection locations ranged from 0.15 to 0.70 m/s (0.5 to 2.3 ft/s) and averaged 0.44 m/s (1.57 ft/s) (Appendix O).

Two hundred and fifty-two (85%) of the 296 white sturgeon eggs collected in 2002 were viable (Figure 6). Egg development ranged from stage 15 to stage 23 (15 to 68 hours post-fertilization). Based on ages of viable eggs and the dates of egg collection, we estimated that white sturgeon spawned during at least eight days in 2002 (Figure 6). The first spawning events were estimated to have occurred on May 31 and the last on June 30. The number of events increased with increasing water temperatures into the first week of June. While a few eggs were collected that back calculated to spawning dates in relatively cold water temperatures (6.5°C on June 7), most of the spawning events occurred when water temperatures were increasing and above 8.0°C.

Table 4. Location (RKM), depth (m), effort, and white sturgeon egg catch by standard artificial substrate mats, Kootenai River, Idaho, 2002.

Geographical description	**River location (RKM)**	**Depth range (m)**	**Total mat days[a]**	**Number white sturgeon eggs**
Lower Shortys Island	227.0-229.5	9.8-12.2	12	0
Middle Shortys Island	229.6-231.5	4.0-25.3	627	296
Myrtle Creek	233.5-234.7	5.5-11.9	29	0
Refuge	234.8-237.5	3.4-24.4	537	0
Deep Creek	237.6-240.5	8.2-13.1	117	0
Hatchery	240.6-243.9	16.0	2	0
US Hwy 95	244.7-246.6	1.5-16.8	480	0
All Sections	227.0–246.6	1.5-25.3	1805	296

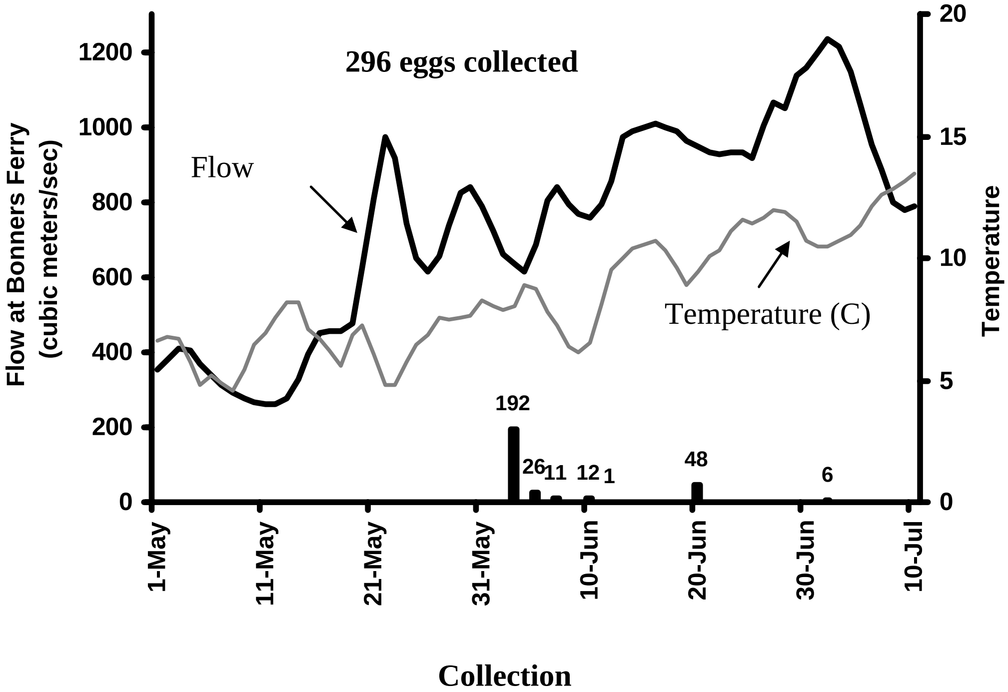
[a] One mat day is one 24-hour set.

Experimental Release of Hatchery White Sturgeon Prejuveniles

The KTOI released 38,400 hatchery white sturgeon embryos during four releases from June 18 through July 8, 2002 (Table 5). One- to seven-day-old embryos were released in the evening during low light periods on the surface above Hemlock Bar (RKM 262.5). No white sturgeon embryos or larvae were collected with the ½ meter or D-ring nets deployed within 45 minutes.

Prejuvenile Sturgeon Sampling

Sampling for white sturgeon embryos and larvae began on June 16 and continued until August 15, 2002. No white sturgeon embryos or larvae were collected. All sampling was conducted during the day. Half-meter nets fished at the surface sampled a total of 195,038 m^3 of water in 99.3 h, captured over 100 catostomidae larvae, several unidentifiable fish larvae, and no fish eggs. Half-meter nets fished at midcolumn depths sampled 189,287 m^3 in 99.6 h, capturing two unidentifiable fish larvae and no fish eggs. D-ring nets fished on the bottom sampled 75,540 m^3 in 106.1 h, capturing no fish larvae and no fish eggs. Duration of sets ranged from 8 min to 3 h 55 min and averaged 1 hr 23 min. Most of the larvae were collected between 14 and 15°C at the Flemming Creek site (RKM 225.5).



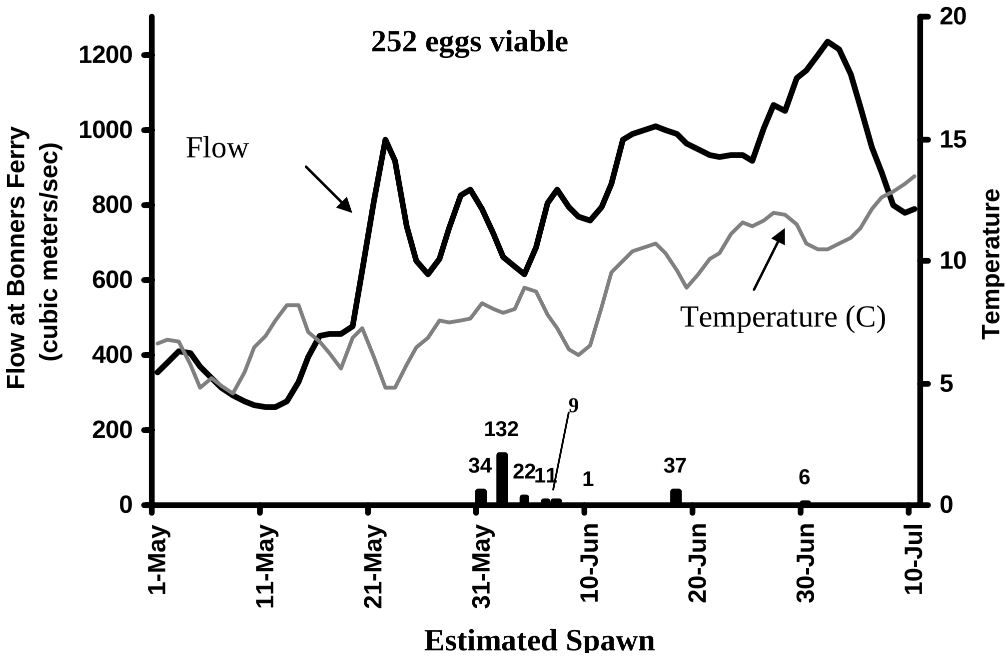


Figure 6. Top figure is collection date, number of eggs, temperature (°C), and flow (m^3/s), Kootenai River at Bonners Ferry, Idaho, 2002. Bottom figure is estimated spawn date, number of eggs, temperature (°C), and flow (m^3/s).

Table 5. Hatchery white sturgeon larvae release date, estimated number of larvae released, and age at release.

Release date	Estimated number released	Age at release (days)
June 18*	15,000	4
June 21	5,100	7
July 3	8,000	4
July 8	10,300	9
Total	38,400	

* - sampling on this date only, no larvae were collected

Juvenile White Sturgeon Sampling

Juvenile sturgeon sampling initiated July 16 and continued through September 24, 2002. Two hundred eighty-six juveniles were captured in gillnets with 328 hours of sampling effort (Tables 1, 6, and 7; Appendices P and Q). Only one wild white sturgeon was captured. One adult sturgeon was captured incidentally while gillnetting for juveniles, and one additional juvenile hatchery sturgeon was captured in a beam trawl tow on July 23.

The highest catch rates were from the 3-inch stretch gillnets followed by 4-inch stretch gillnets (Table 6). Most (75%) of the sampling effort was on the five prime juvenile rearing areas, and 25% of the effort was on seven marginal habitat sites. Ferry Island (RKM 205.5) and Rock Creek (RKM 215.5) had the highest catch rates, and RKM 230.5 had the lowest catch rates with no juvenile sturgeon captured (Table 7). Of the 287 individuals sampled, 29 families (from the KTOI hatchery) were represented and 40 individuals from family BC 197. The 1999 year-class was well represented with 125 individuals collected. The average fork and total lengths of the 286 juveniles sampled was 39.0 cm and 45.3 cm, respectively, and weight averaged 0.44 kg (Table 8). Details on sizes and numbers of hatchery white sturgeon stocked in the Kootenai River since 1990 are given in Appendix P, and specific growth parameters of the juvenile white sturgeon captured in 2002 are listed in Appendix Q.

Thirty-four hatchery sturgeon were euthanized and their stomachs removed for food habit analysis. Chironomid larvae were the most common food item in the sturgeon stomachs. Additionally, 51 pectoral fin ray sections were removed from hatchery-reared sturgeon and wild sturgeon in 2002 to evaluate growth pattern of known-age hatchery sturgeon and to determine age of wild sturgeon. Data will be used to update aging sections of a white sturgeon database. Sixty-three pectoral fin ray punches were taken from hatchery sturgeon captured while gillnetting to determine and substantiate the presence of white sturgeon Iridovirus in the Kootenai River.

Relative Weights of Adult and Juvenile White Sturgeon

We calculated fork length relative weight (Beamesderfer 1993) for 46 adult white sturgeon captured in March and April 2002. Fork length relative weight for adult white sturgeon ranged from 34 to 115 with a mean of 88 (SD = 14). Calculated fork length relative weight for 348 juvenile hatchery white sturgeon from the 1991, 1992, 1995, 1998, 1999, and 2000 year classes captured during July and August 2002 ranged from 33 to 346 with a mean of 92 (SD = 22).

Table 6. Idaho Department of Fish and Game juvenile white sturgeon gillnet sampling effort by mesh size for July and August 2002.

Gillnet mesh size	Number of sets	Hours of effort	Number of adults captured	Number of juveniles captured	Sturgeon catch per unit of effort
1.5” stretch	68	63.7	0	32	0.5024
2” stretch	92	107.8	0	90	0.8349
3” stretch	62	60.9	0	99	1.6256
4” stretch	43	58.1	0	53	0.9122
6” stretch	29	37.8	1	12	0.3175

Table 7. Idaho Department of Fish and Game juvenile white sturgeon gillnet sampling effort by sampling location for July and August 2002.

River Kilometer	Number of sets	Hours of Effort	Number of adults captured	Number of juveniles captured	Sturgeon catch per unit of effort
176.5	9	9.4	0	5	0.5319
182.0	21	24.3	0	4	0.1646
190.3	10	16.0	0	8	0.5000
205.5	99	117.6	1	162	1.3776
208	20	27.0	0	10	0.3704
215.5	54	47.5	0	79	1.6632
225.0	29	26.2	0	13	0.4962
227.8	20	22.6	0	4	0.1770
230.5	7	7.7	0	0	0
234.5	25	30.0	0	1	0.0333

Table 8. Vital statistics of juvenile hatchery white sturgeon recaptures from summer 2002 gillnet sampling by the Idaho Department of Fish and Game.

	Statistic	FL (cm)	TL (cm)	WT (kg)
Recaptures N = 286	Average	39.0	45.3	0.44
	Standard deviation	11.36	13.0	0.44
	Minimum	20.9	26.2	0.05
	Maximum	74.0	87.6	6.0

DISCUSSION

Peak spring flows from Libby Dam in 2002 were nearly twice that of 2001 and the highest in over a decade due to snow pack exceeding 120% of average and rapid late May snowmelt. Flows remained high through May, and substrate mat sampling proved very difficult as many mats were buried in depositional sand or were swept downriver with debris. Interestingly, despite the extreme differences in temperature and flow between 2001 and 2002, estimated spawning event dates were remarkably similar between years, and the total number of spawning events and the total number of eggs collected were not largely influenced by flow rates or sampling effort.

White sturgeon spawning events during the years 1994 through 2000 were compared to daily average flow and daily average temperature at Bonners Ferry for each event (Paragamian and Wakkinen 2002). White sturgeon often spawned during decreasing flows, and the number of events each year ranged from as few as nine to as many as 20, with the number of days during the spawning period ranging from 17 to 31 days. The most consistent year of Kootenai River white sturgeon spawning was 1996 when spawning was detected during 18 of 19 days; flow ranged from 891 to 1,259 m^3/s (31,465-44,461 cfs) and averaged about 1,131 m^3/s (~40,000 cfs) for the first 11 events before there was a day of undocumented spawning. Average daily temperature during spawning ranged from 7.5 to 14°C (45.5-57.2°F), with the highest probability of spawning (48%) at the 9.5-9.9°C (49.1-49.9°F) range.

Flow was an important variable affecting sturgeon spawning. Average daily flow for spawning events ranged from 141 to 1,265 m^3/s (4,979-44,673 cfs), but most (63%) spawning took place above 630 m^3/s (22,248 cfs) (Paragamian and Wakkinen 2002). Analysis suggests flows for optimum white sturgeon spawning in the Kootenai River should be held above 630 m^3/s (22,248 cfs), an ideal temperature range of 9.5 to 12°C (49.1-53.6°F), and a duration of 42 d, which is based on recommendations in the Kootenai River White Sturgeon Recovery Plan (USFWS 1999). As previously noted, the most consistent spawning took place at an average of about 1,131 m^3/s (~40,000 cfs). However, of the two variables, temperature is the most difficult to control.

A spill test at Libby Dam scheduled during late June 2002 was designed to gather information necessary to develop an understanding of the gas exchange processes in the river downstream of Libby Dam, particularly dissolved gas production from spillway releases and how total dissolved gas levels are affected by mixing and other processes in the river downstream from the dam. Spill has also been promoted as a means of increasing spawning and rearing flows for Kootenai River white sturgeon. By knowing how different spill amounts affect downstream gas levels, the USACE can better manage spill to avoid harmful impacts of extremely high total dissolved gas levels on downstream aquatic life (such as fish and aquatic insects). As the spill test transitioned to a flood control spill that lasted until early July, it provided us the opportunity to test how maximum discharge from Libby Dam impacts white sturgeon behavior and sedimentation or scouring rates along the Kootenai River. Because U.S. Geological Survey (USGS) sedimentation studies were done in conjunction with this test, this spill test may prove to be an important first step toward determining how much water volume is necessary to clean sand and sediment from spawning areas. A report will be released by the USGS in 2004 on sediment transportation in the Kootenai River.

In 2002, most of the white sturgeon spawned during the first week of June, about three weeks prior to the spill test. The well-documented spawning behavior of Kootenai River white sturgeon (Paragamian and Kruse 2001; Paragamian et al. 2002) would be useful information to consider when designing and planning for future spill tests, and might provide better spawning and rearing conditions for adult and larval white sturgeon.

River stage at Bonners Ferry during the spill test reached a maximum of 1761.77 ft (above mean sea level [MSL]) on July 2. Prior to 1992, flood stage at the Bonners Ferry gage was identified as 1770 ft MSL by the USACE. The Columbia River System Operation Review (SOR) placed Bonners Ferry flood stage at elevation 1766.5 ft MSL. Both of these elevations were thought to be too high based on levee elevation work done from 1995-1997 by USACE water surface profile modeling. The best available modeling suggests that river elevation in excess of 1764 ft MSL may eventually result in levee failure in the reach from Bonners Ferry to the Canadian border. Flood control space permitting, to date, the USACE attempts to regulate the Kootenai River to no higher than 1764 ft MSL at the Bonners Ferry gage (USACE 1998). Flows from the 2002 spill test caused minimal damage. There were approximately five outbuildings in the Libby/Troy area that were affected by the flows but no homes. In a survey done in 2003, a few farmers reported crop losses of less than two acres in 2002 (Layna Goodman, USACE, personal communication).

Over 10 years of intense substrate mat monitoring has yielded a vast amount of information on how flow and temperature affect the spawning behavior of Kootenai River white sturgeon. In 2002, most (75%) of the estimated spawn dates occurred when water temperatures were increasing and on the descending limb of the hydrograph, and spawning essentially ceased when water temperatures dropped below about eight degrees (Figure 6). This validates previous studies on white sturgeon spawning behavior in the Kootenai River (Paragamian et al. 2002). At this point, we have a good grasp of the timing of Kootenai River white sturgeon spawning. Rather than continuing to monitor and evaluate each spawning event throughout the entire spawning season, substrate mat sampling could be used as an index to document the beginning of the spawning season. The collection of the first eggs would serve as a benchmark to initiate other types of monitoring and evaluation programs, and could be used by regulatory agencies (USACE) as a trigger to initiate the release of water from Libby Dam.

This year, depth sensitive radio telemetry focused on one late vitellogenic female white sturgeon, and her geographic position and movements were monitored from prespawn to postspawn. The study was designed to locate the individual's geographic position at 20-minute intervals for each eight-hour period and collect the depth (water depth) and pulse frequency (fish depth) at each geographic position. It was difficult to collect accurate data, especially the depth of water at each exact position, without changing the behavior of the fish by the boat movement. This study was designed to provide us with two important aspects of depth preference: 1) the fish depth determined from the transmitters, and 2) the depth of the fish determined from the transmitters with respect to the total depth of water (depth ratio). Data obtained from the first aspect simply tells us if there is a preferred depth and might suggest where white sturgeon reside in the water column with respect to the total depth. Data obtained from the second aspect may be erroneous for several reasons. Depth can change quickly (several meters) within a few boat lengths, and as mentioned above, determining geographic position, water depth, and pulse frequency simultaneously or before the boat drifts off the spot and without using mechanization to maintain location (and changing behavior) is very difficult. Nonetheless, two years of data suggests that white sturgeon spend most of their time near the bottom of the Kootenai River, and it appears that when sturgeon are moving the most vertically in the water column, they are also exhibiting the greatest horizontal movement. The individual female that we studied this year exhibited periods of very little movement and periods of almost constant movement within a 1 km area. This constant movement or searching behavior, especially during the spawning period, suggests that the fish may not have been able to find some biological cue, such as proper substrate or a certain current velocity. It would be valuable to compare this behavior of Kootenai River white sturgeon to that of other white sturgeon populations that are successfully spawning and recruiting. Perhaps an unexpected bonus of this research was the detailed movement and behavioral record that developed by locating an individual four times an hour for eight hours several times a week at all hours of the day. The 2003 season will be the last year of data collection for the depth sensitive studies, and that annual report will provide more detailed analysis, discussions, and conclusions.

The BioSonic dual beam echo sounder station located on the bank of the Kootenai River successfully detected adult white sturgeon passing through the beam. This suggests that an active hydroacoustic dual beam echo sounder station (where pulses of sound are transmitted from a transducer into the water to reflect off objects such as fish) situated horizontally from the target along the river's edge can be used to detect sturgeon passing through the beam. These results were significant in light of the fact that hydroacoustics have not previously been used in this way to detect white sturgeon. We detected at least four radio-tagged suspected spawners, including two females (numbers 996 and 1581) and two males (numbers 504 and 993). The fish detected by the echo sounder were verified by simultaneous locations at the fixed receiver site and/or through boat telemetry in the area. Successfully detecting sturgeon through "horizontal hydroacoustics" enabled us to begin to determine mean target strength for sturgeon in the Kootenai River, which is critical for future efforts using echo sounders, for example, to determine either biomass or abundance of spawning fish. Target strength is a critical parameter of all aspects of hydroacoustics. It is the acoustic reflectivity or acoustic size of the target being surveyed, normally expressed in decibels (dB), and is a function of the cross-sectional size of the target and the density difference between water and the component parts of the target (i.e. bones, scales, flesh, gas bladder, etc). Data collected this year will enable us to look at target strength for a variety of sturgeon sizes and orientations, which can be used to design future studies using echo sounders.

While no prejuvenile sturgeon were collected in 2002, over 100 non-sturgeon larvae were collected, which is the most since sampling began in 1989. It is unknown whether this relatively high catch is a result of a better sampling design, increased effort, or the result of high natural recruitment of the non-target species. Contrary to previous years when the D-ring nets fished near bottom had the highest catch, in 2002 all larvae sampled were from the midcolumn and surface nets. This may be an artifact of high water velocities (increased effort), or it may be that high water provided ideal conditions for recruitment (physically or production-wise) or ideal conditions for drift. Nonetheless, most of the larvae collected were from surface nets, which is a new phenomenon for this type of sampling on the Kootenai River.

After 10 years of radio and sonic telemetry monitoring, few if any adult white sturgeon have been located or observed moving above Bonners Ferry where substrates are more suitable for egg hatching and larval development. Contrary to other white sturgeon populations and other North American sturgeon species that spawn over gravel and cobble substrate (Kempinger 1988; Parsley et al. 1993; Kieffer and Kynard 1996), Kootenai River white sturgeon are spawning almost exclusively over shifting sand substrate. Gravel and cobble substrates are thought to provide protection from egg and larval predators by physically providing space and places for the eggs to adhere, and usually these substrate types result from higher velocities, which may act as a feeding barrier to some predators. Shifting sand substrate may also cause mortality by physically suffocating the eggs. We have collected literally thousands of eggs in 10 years of substrate sampling, but few juveniles and virtually no larvae have been collected since the mid-1960s, leading to a survival bottleneck. Mortality has essentially eliminated recruitment somewhere between the fertilized egg stage and the first year class. While trying to document larval recruitment from a limited and diminishing adult spawning stock seems challenging, Auer and Baker (2002) have been effectively sampling larval lake sturgeon from the Sturgeon River, Michigan, a river with a much smaller watershed and much smaller spawning stock.

Moving spawning adults upstream to gravel/cobble substrates may provide the rare opportunity to refine our survival bottleneck theory and may provide vital information on spawning microhabitat requirements for future artificial spawning habitat projects.

RECOMMENDATIONS

1. As soon as water temperature reaches 7°C (43°F) after April 1, provide 425 m^3/s (15,000 cfs) flow at Bonners Ferry with stable or increasing temperature to initiate and maintain spawning migration of Kootenai River white sturgeon.

2. Provide flows of a minimum of 630 m^3/s (22,248 cfs) for 42 d (as prescribed for spawning and rearing in the Kootenai River White Sturgeon Recovery Plan) at Bonners Ferry once water temperatures of 8°C to 10°C (46°F to 50°F) are reached to stimulate spawning and optimize egg/larval survival of Kootenai River white sturgeon.

3. Evaluate the role of substrate composition (sand vs. cobble substrate) in the apparent failure to recruit white sturgeon juveniles from successful spawning events.

4. Unite up to 20 mature white sturgeon (15 males and 5 females) with suitable spawning substrates by moving them during the prespawning and spawning season to the Hemlock Bar reach (rkm 262.0).

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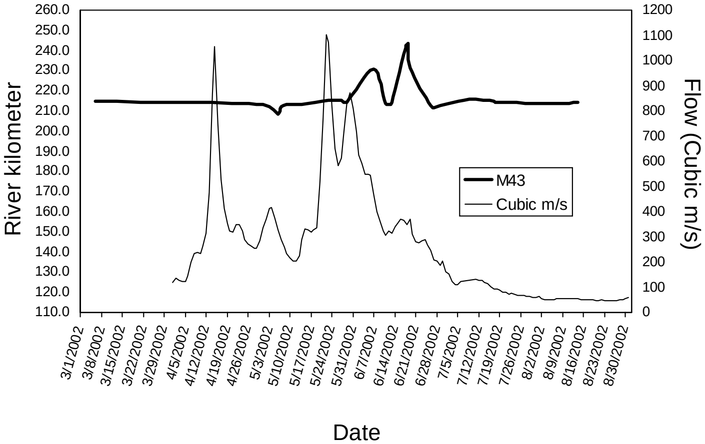
APPENDICES

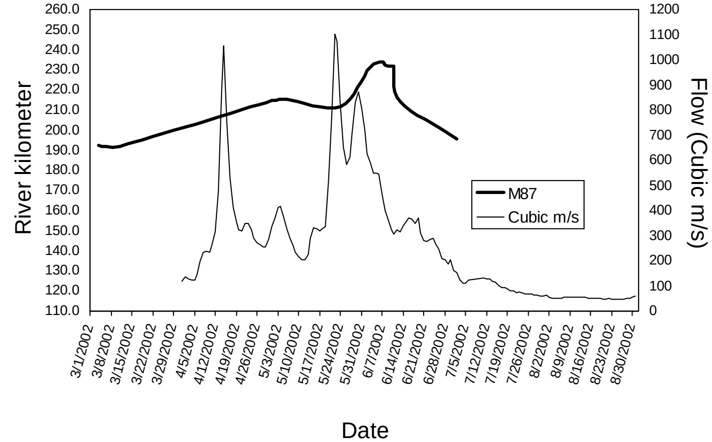
Appendix A. Sexual development of white sturgeon sampled and biopsied by Idaho Department of Fish and Game in the Kootenai River, Idaho, 1989 through 2002.

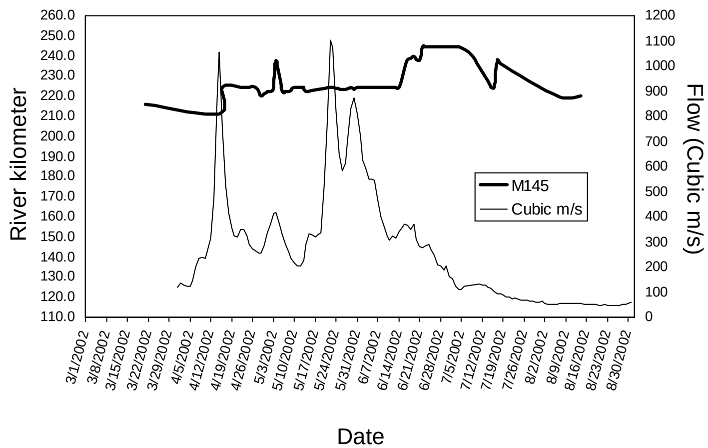
Categories of sexual development		Percent (number) of sample by year													
Category/ Sex	**Description of development**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995[a]**	**1996[a]**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
0/Unknown	Gonad undifferentiated or not seen	34 (61)	14 (16)	10 (4)	4 (1)	16 (6)	26 (15)	9 (2)	12 (5)	10 (6)	13 (6)	9 (4)	10 (6)	19 (10)	13 (2)
1/Female	Previtellogenic: No visual signs of vitellogenesis; eggs present but have avg. diameter <0.5 mm	13 (23)	12 (13)	8 (3)	11 (3)	5 (2)	5 (3)	9 (2)	8 (3)	17 (10)	15 (7)	9 (4)	8 (5)	21 (11)	13 (2)
2/Female	Early vitellogenic: Eggs are cream to gray; avg. diameter 0.6-2.1 mm	6 (12)	7 (8)	5 (2)	4 (1)	10 (4)	2 (1)	0	5 (2)	0	15 (7)	2 (1)	7 (4)	6 (3)	0
3/Female	Late vitellogenic: Eggs are pigmented & attached to ovarian tissue; avg. diameter 2.2-2.9 mm	5 (10)	5 (5)	11 (4)	12 (3)	8 (3)	5 (3)	0	3 (1)	2 (1)	5 (2)	5 (2)	2 (1)	2 (1)	1 (1)
4/Female	Ripe: Eggs are fully pigmented & detached from ovarian issue; avg. diameter 3.0-3.4 mm	2 (3)	5 (5)	0	0	3 (1)	14 (8)	27 (6)	15 (6)	10 (6)	2 (1)	24 (10)	15 (9)	9 (5)	40 (6)
5/Female	Spent: Gonads are flaccid & contain some residual fully pigmented eggs	3 (5)	1 (1)	3 (1)	0	0	0	5 (1)	0	0	0	0	0	0	0
6/Female	Previtellogenic with attritic oocytes: Eggs present but have an average diameter <0.5 mm; dark pigmented tissue present that may be reabsorbed eggs	2 (3)	0	0	0	0	0	0	5 (2)	3 (2)	0	0	0	0	0
R/Female	Reabsorbing eggs	0	0	0	4 (1)	0	0	0	0	0	0	0	0	0	0
7/Male	Non-reproductive: Testes with translucent smoky pigmentation	3 (5)	27 (30)	34 (13)	38 (10)	8 (3)	19 (11)	23 (5)	30 (12)	23 (14)	13 (6)	35 (15)	29 (18)	19 (10)	20 (3)
8/Male	Reproductive: Testes white with folds & lobes	32 (58)	28 (31)	18 (7)	27 (7)	47 (18)	29 (17)	27 (6)	20 (8)	35 (21)	37 (17)	16 (7)	29 (18)	24 (13)	13 (2)
9/Male	Ripe: Milt flowing; large white lobular testes	0	1 (1)	3 (1)	0	0	0	0	0	0	0	0	0	0	0
S/Male	Spent: Testes flaccid; some residue of milt	0	0	8 (3)	0	3 (1)	0	0	3 (1)	0	0	0	0	0	0

[a] Surgeries were carried out on fish that externally appeared to be candidates for spawning.

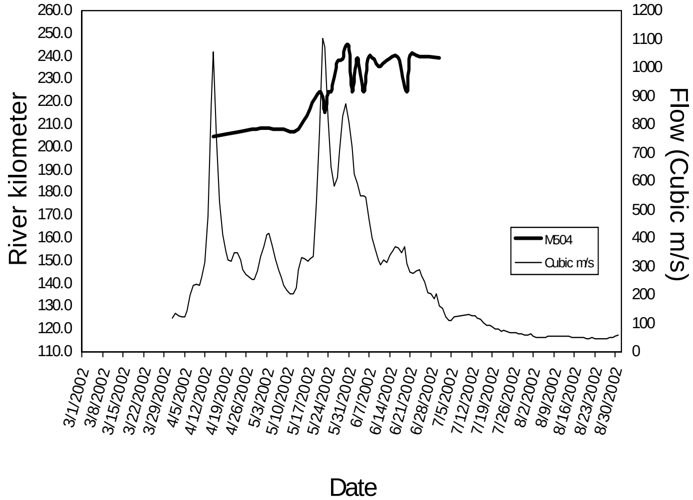
Appendix B. Migration and flow (m^3/s) for three of six adult male white sturgeon, all three of which are believed to have spawned in the Kootenai River, Idaho, 2002.

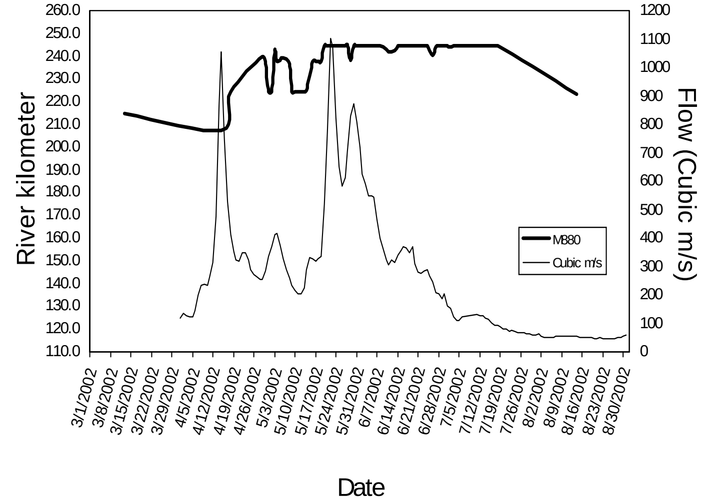


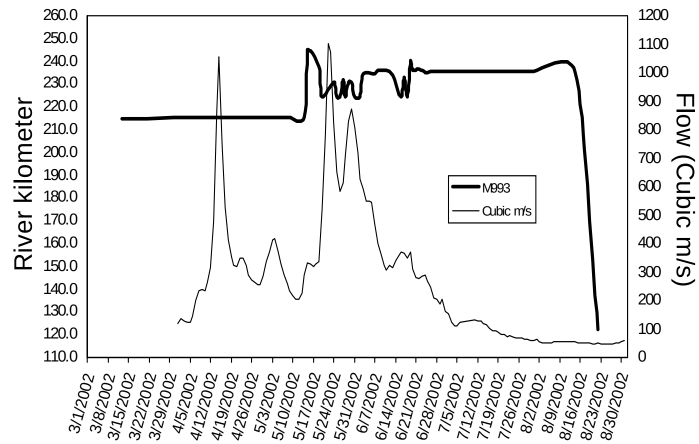




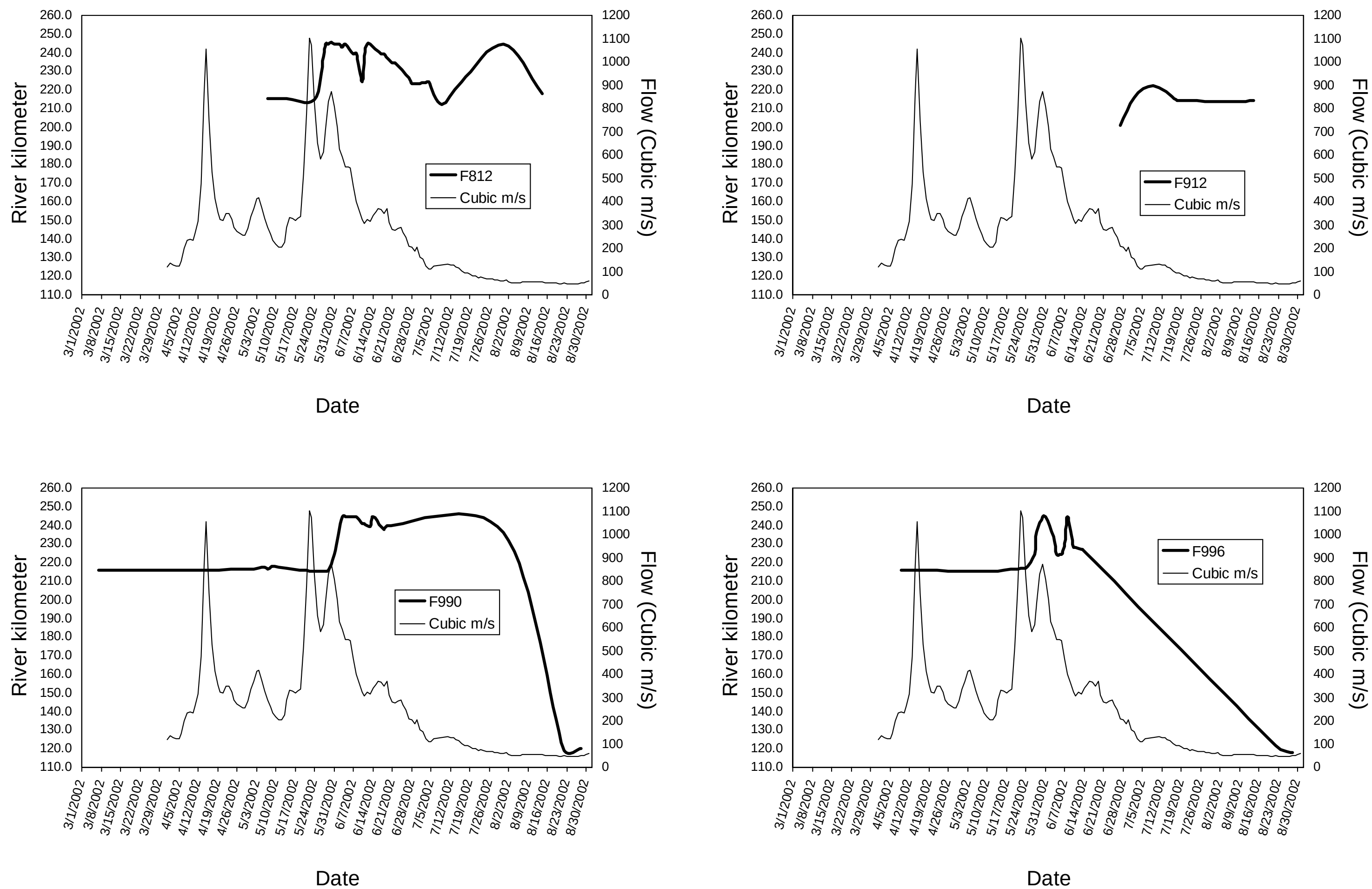
Appendix C. Migration and flow (m^3/s) for three of six adult male white sturgeon, all three of which are believed to have spawned in the Kootenai River, Idaho, 2002.



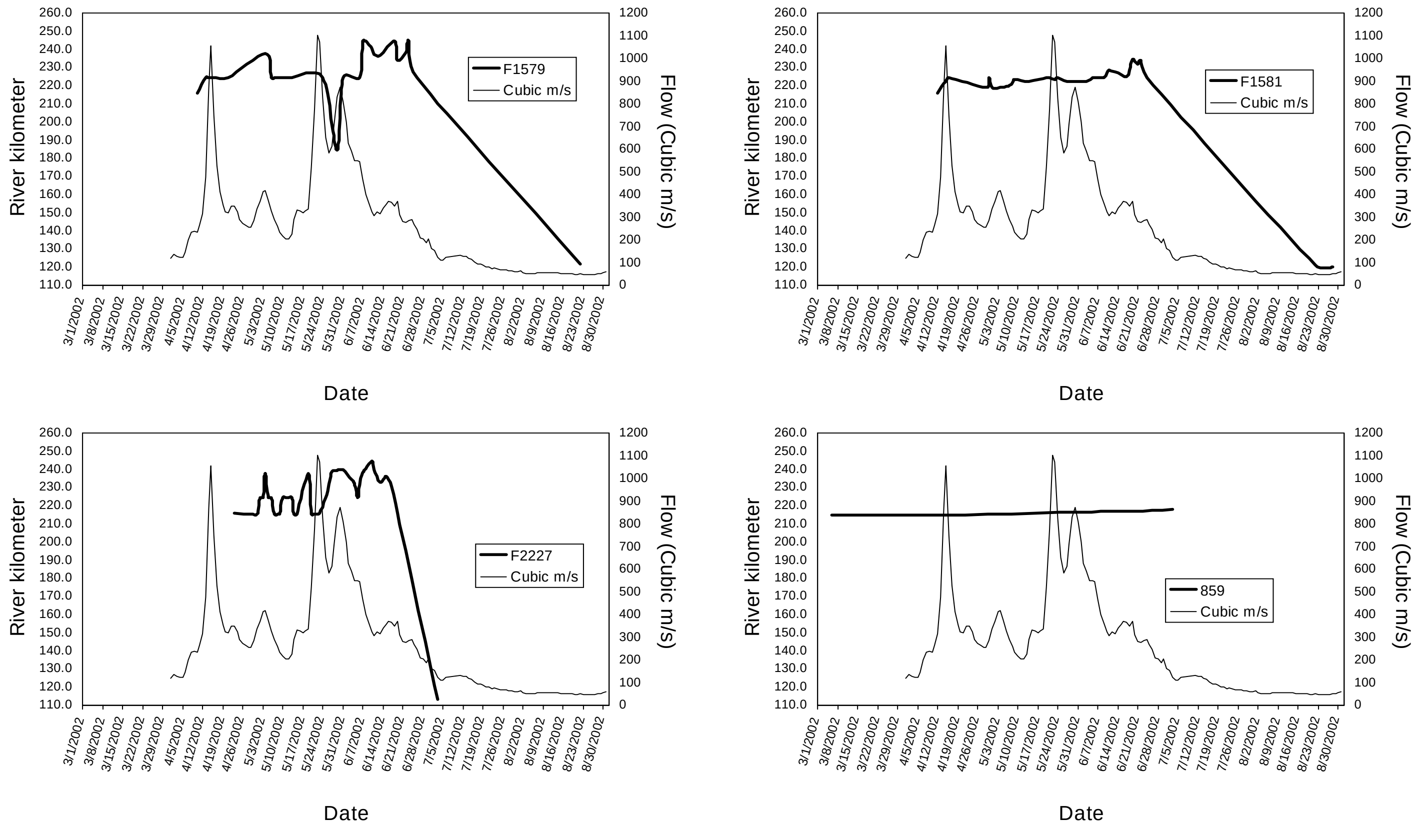




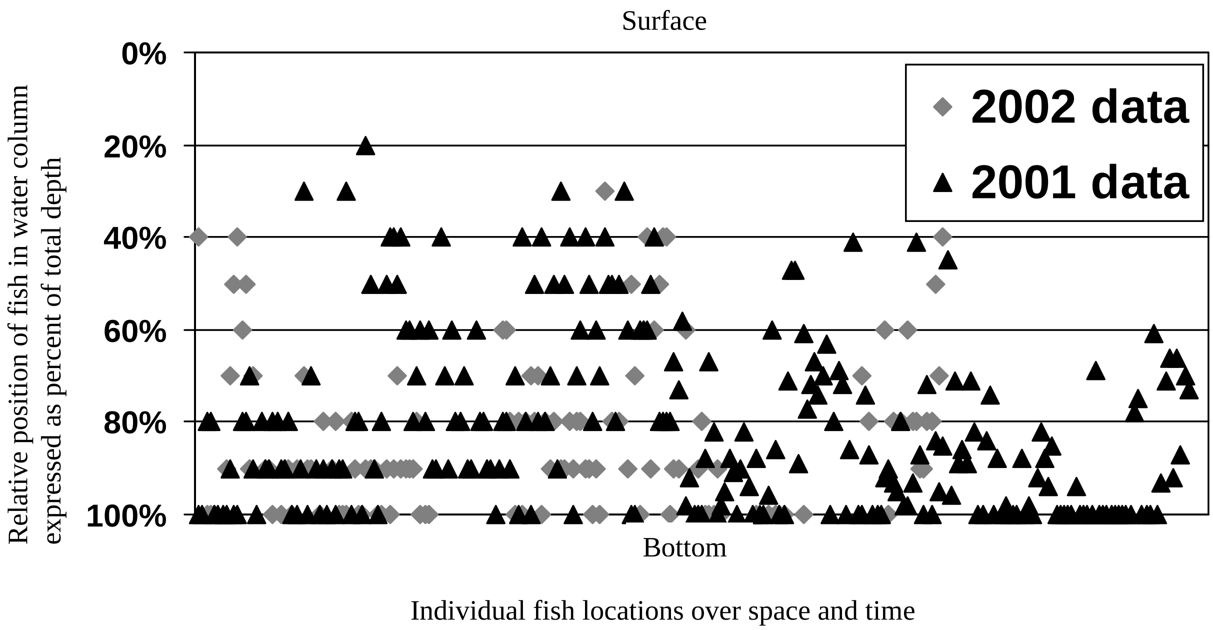
Appendix D. Migration and flow (m^3/s) for four of seven adult female white sturgeon, all four of which are believed to have spawned in the Kootenai River, Idaho, 2002.



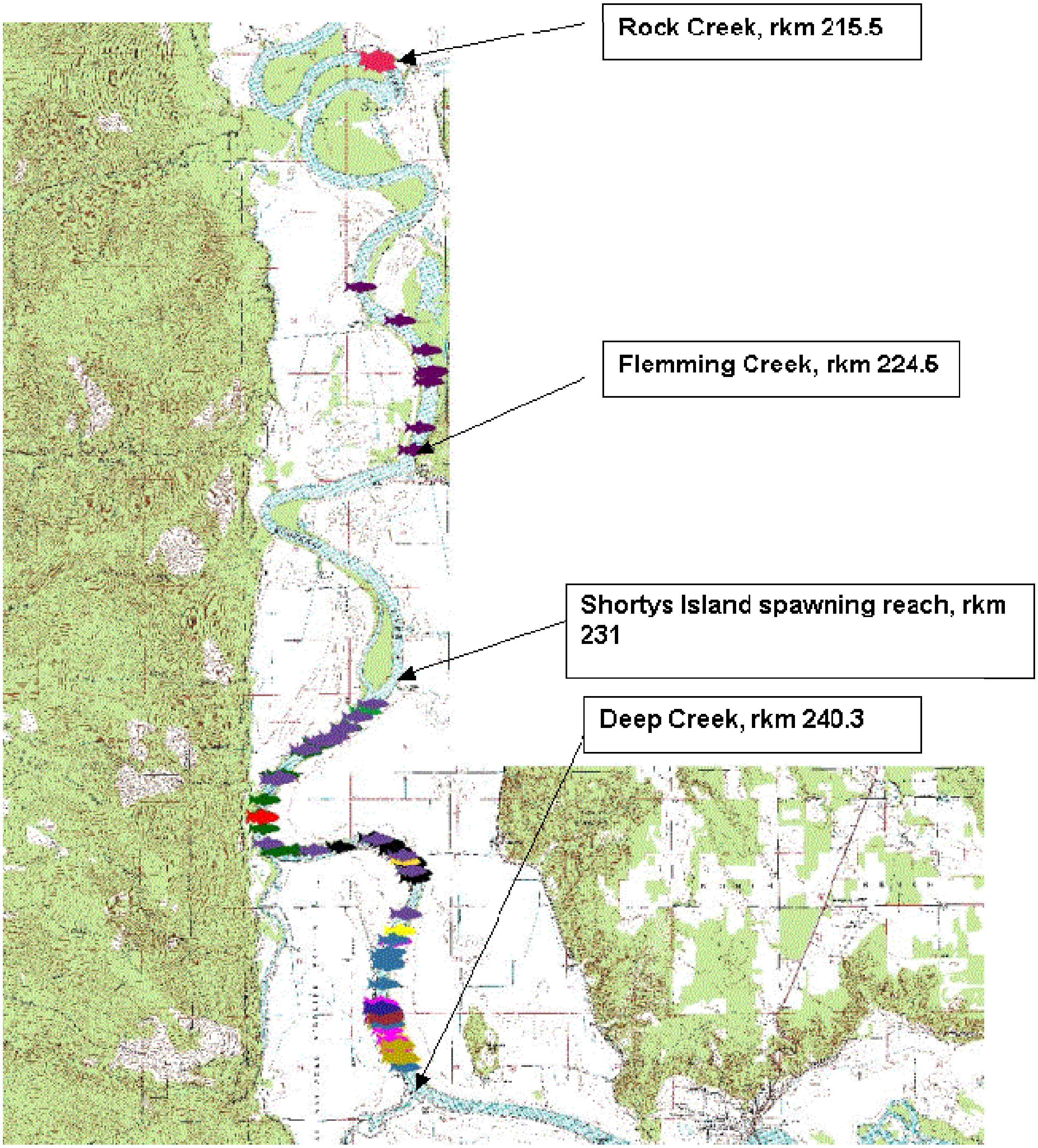
Appendix E. Migration and flow (m^3/s) for three of seven adult female white sturgeon and one adult of undetermined sex; all three females are believed to have spawned in the Kootenai River, Idaho, 2002.



Appendix F. A scatter plot of relative position in the water column of white sturgeon with depth sensitive transmitters, Kootenai River, Idaho, 2001 and 2002.



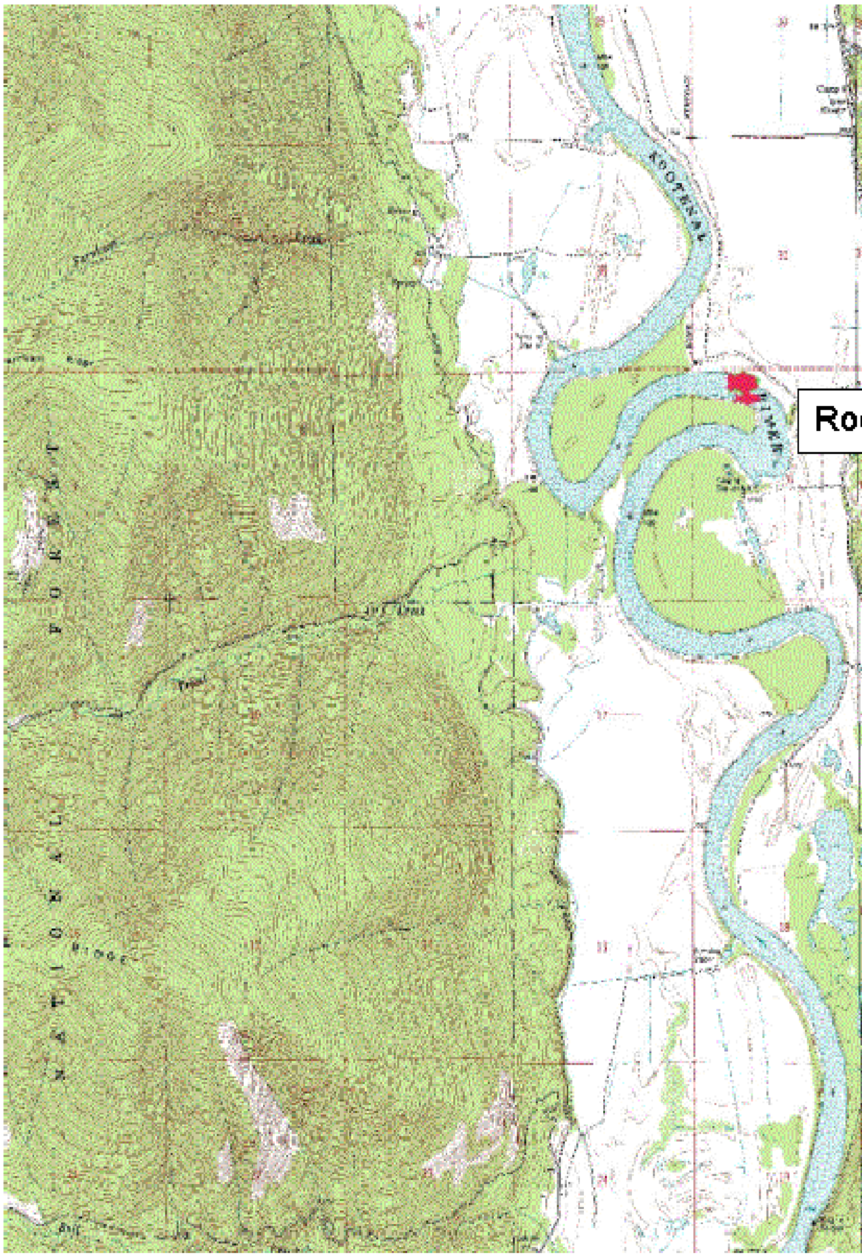
Appendix G. Study area and telemetry locations for white sturgeon depth sensitive radio telemetry and behavior studies May 15 through June 17, 2002, Kootenai River, Idaho. Fish symbols with different colors signify different sampling dates. The number of fish symbols of each color signifies the number of times the fish was located each day.



Appendix H. Study area and telemetry locations for white sturgeon depth sensitive radio telemetry and behavior studies May 15 through May 21, 2002, Kootenai River, Idaho. Fish symbols with different colors signify different sampling dates. The number of fish symbols of each color signifies the number of times the fish was located each day.

Fish staged from 05/15 to 05/21 at Rock Creek

Very little movement during this period

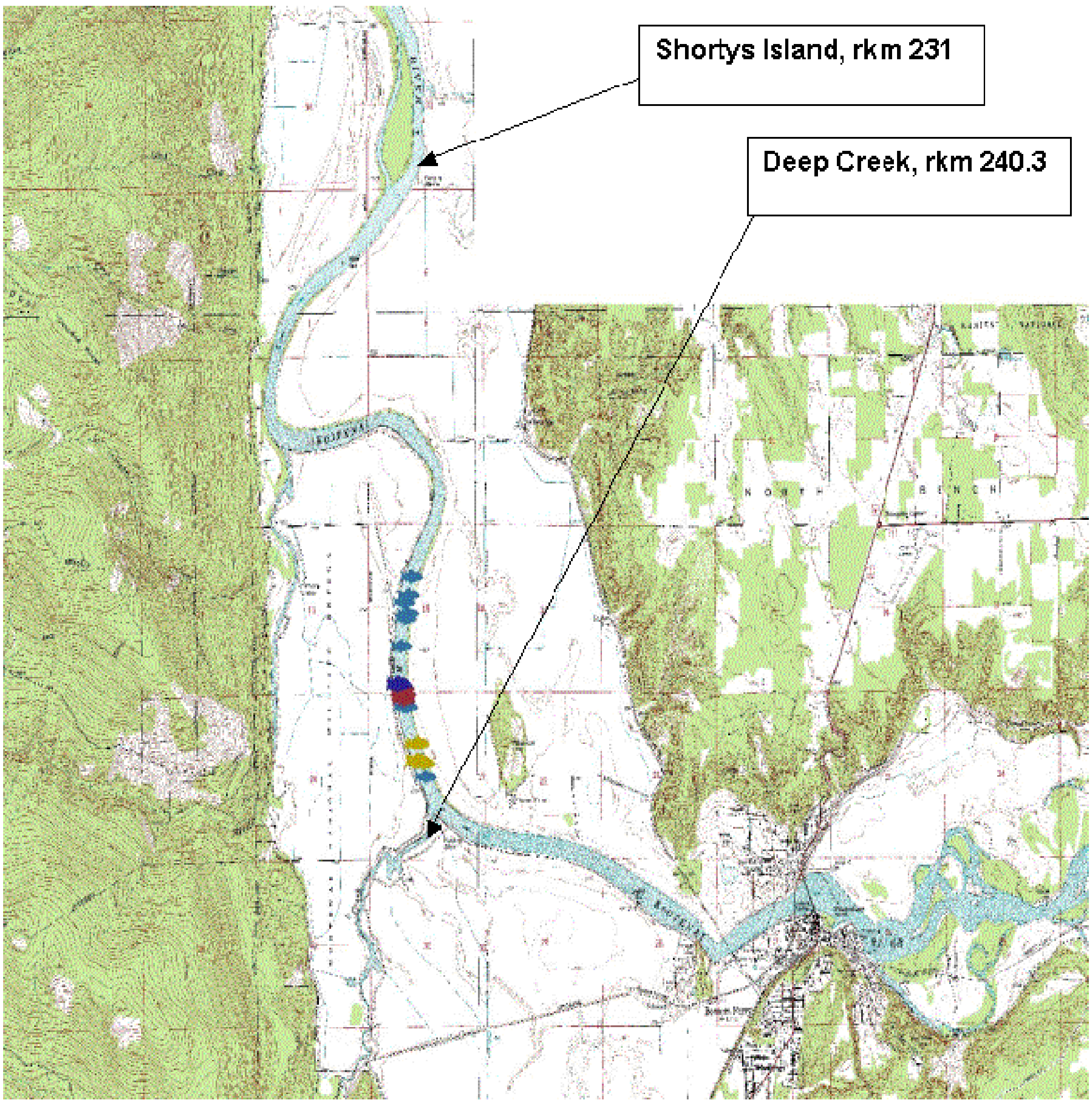


Rock Creek

Appendix I. Study area and telemetry locations for white sturgeon depth sensitive radio telemetry and behavior studies May 27 through May 31, 2002, Kootenai River, Idaho. Fish symbols with different colors signify different sampling dates. The number of fish symbols of each color signifies the number of times the fish was located each day.

From 05/27 through 05/31, fish moved up from Rock Creek to Deep Creek area.

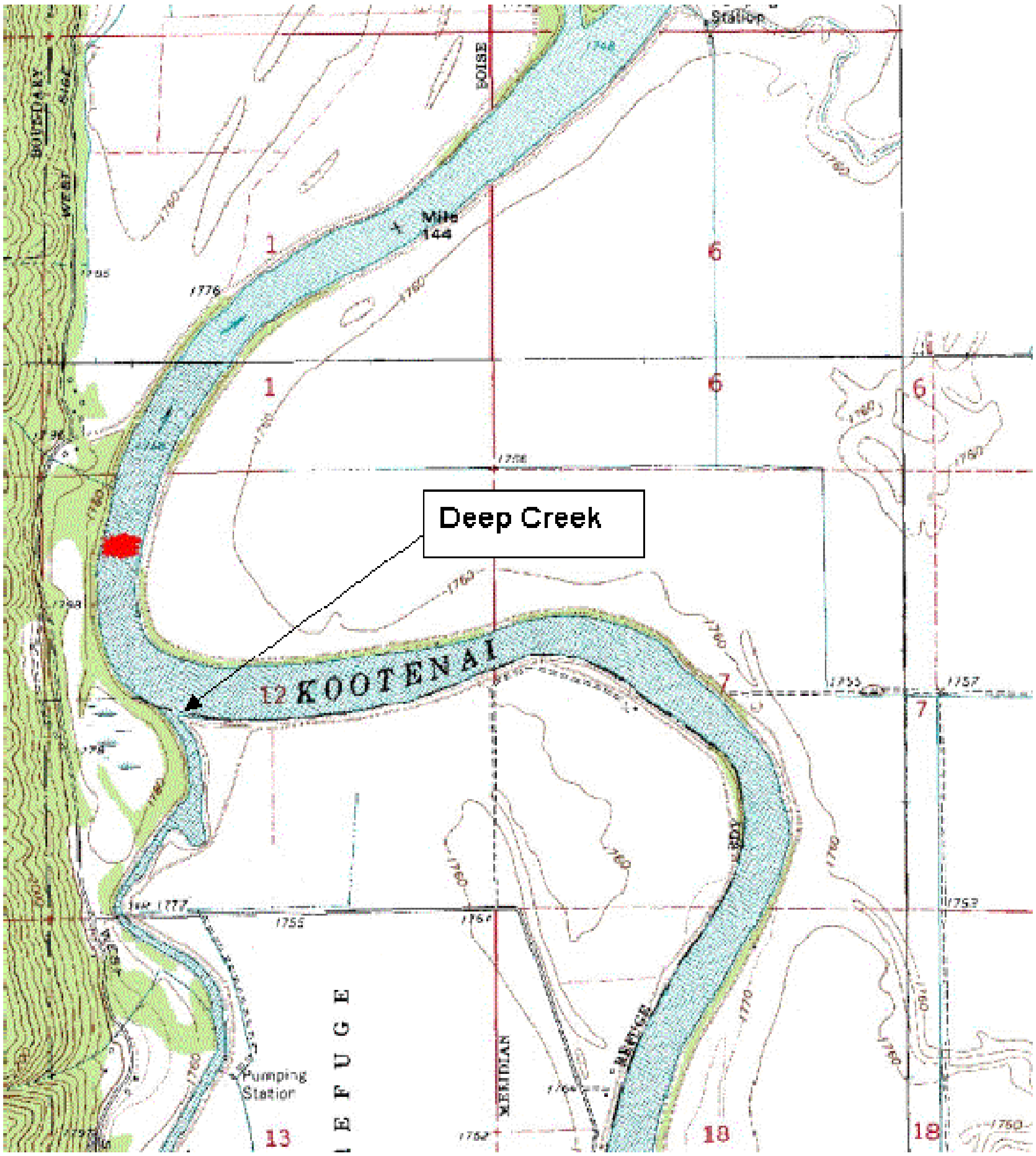
Small erratic movements



Appendix J. Study area and telemetry locations for white sturgeon depth sensitive radio telemetry and behavior studies June 3, 2002, Kootenai River, Idaho. Fish symbols with different colors signify different sampling dates. The number of fish symbols of each color signifies the number of times the fish was located each day.

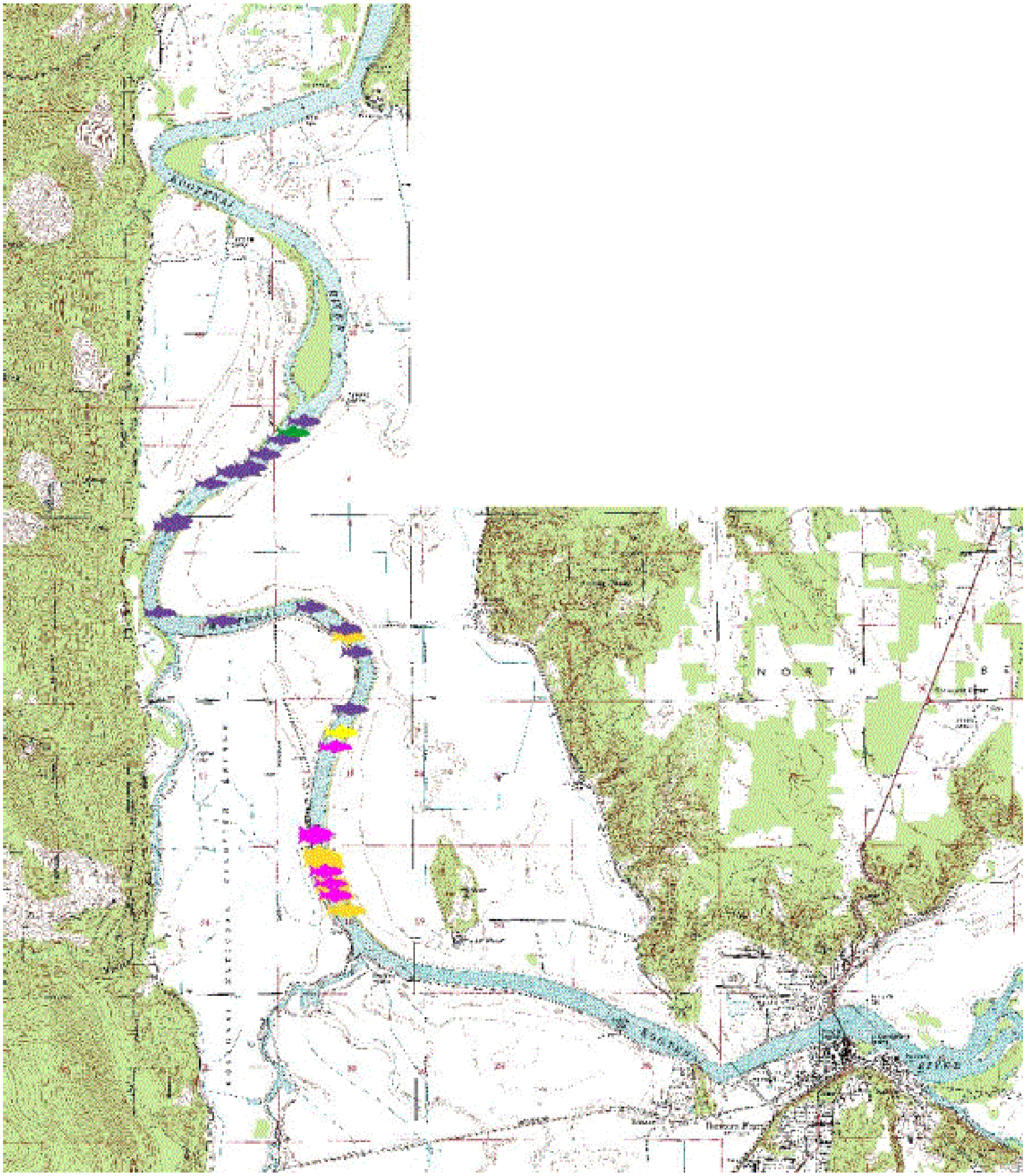
June 03, 8 locations in small area below Deep Creek

Very little movement



Appendix K. Study area and telemetry locations for white sturgeon depth sensitive radio telemetry and behavior studies June 4 through June 8, 2002, Kootenai River, Idaho. Fish outlines indicate geographic locations at various times. Fish symbols with different colors signify different sampling dates. The number of fish symbols of each color signifies the number of times the fish was located each day.

June 4, 6 and 8, erratic movements between Deep Creek and Shortys Island

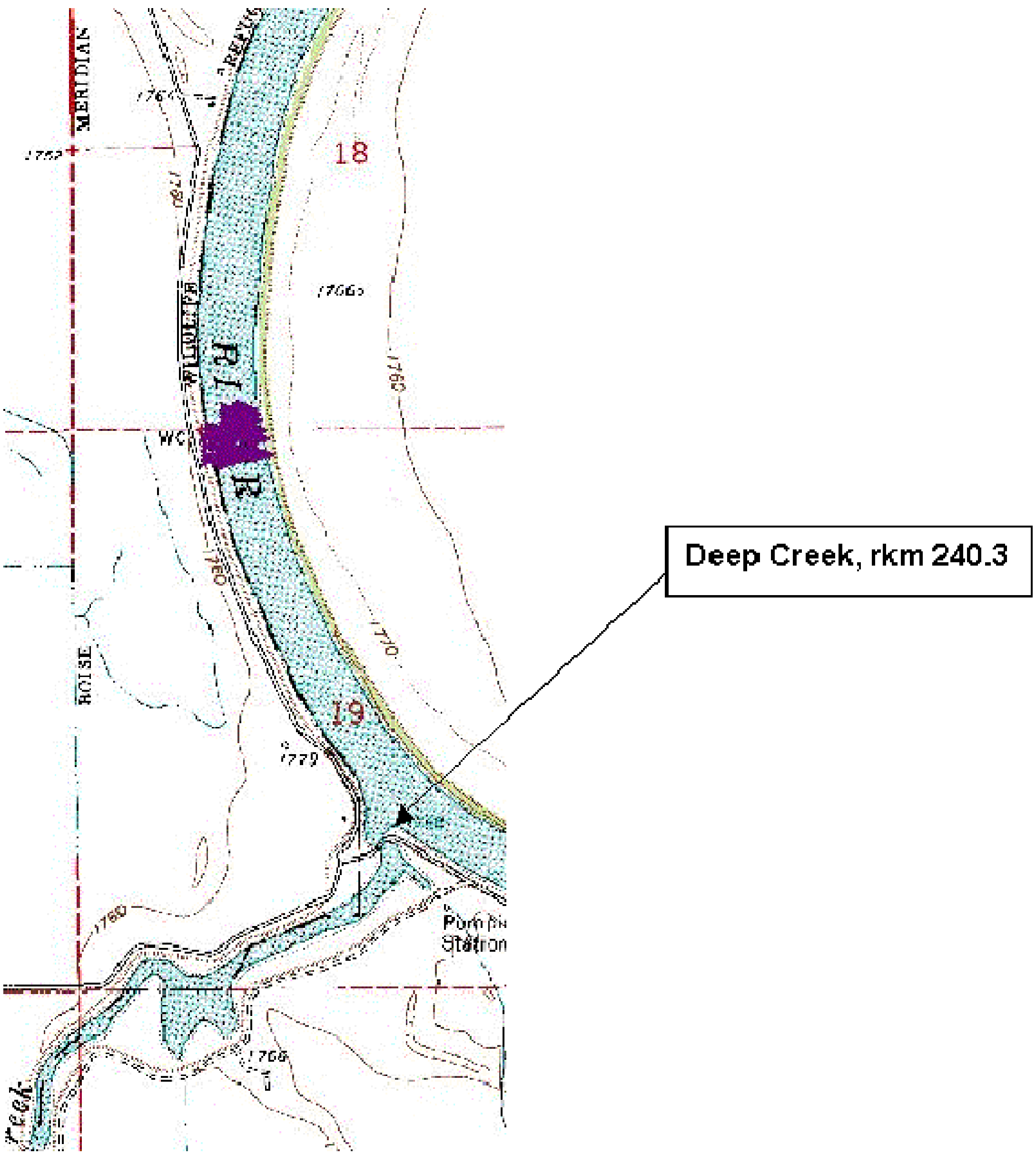


Appendix L. Study area and telemetry locations for white sturgeon depth sensitive radio telemetry and behavior studies June 10, 2002, Kootenai River, Idaho. Fish symbols with different colors signify different sampling dates. The number of fish symbols of each color signifies the number of times the fish was located each day.

June 10, fish moved back down to Deep Creek

20 locations during evening into night from 16:27 to 23:40

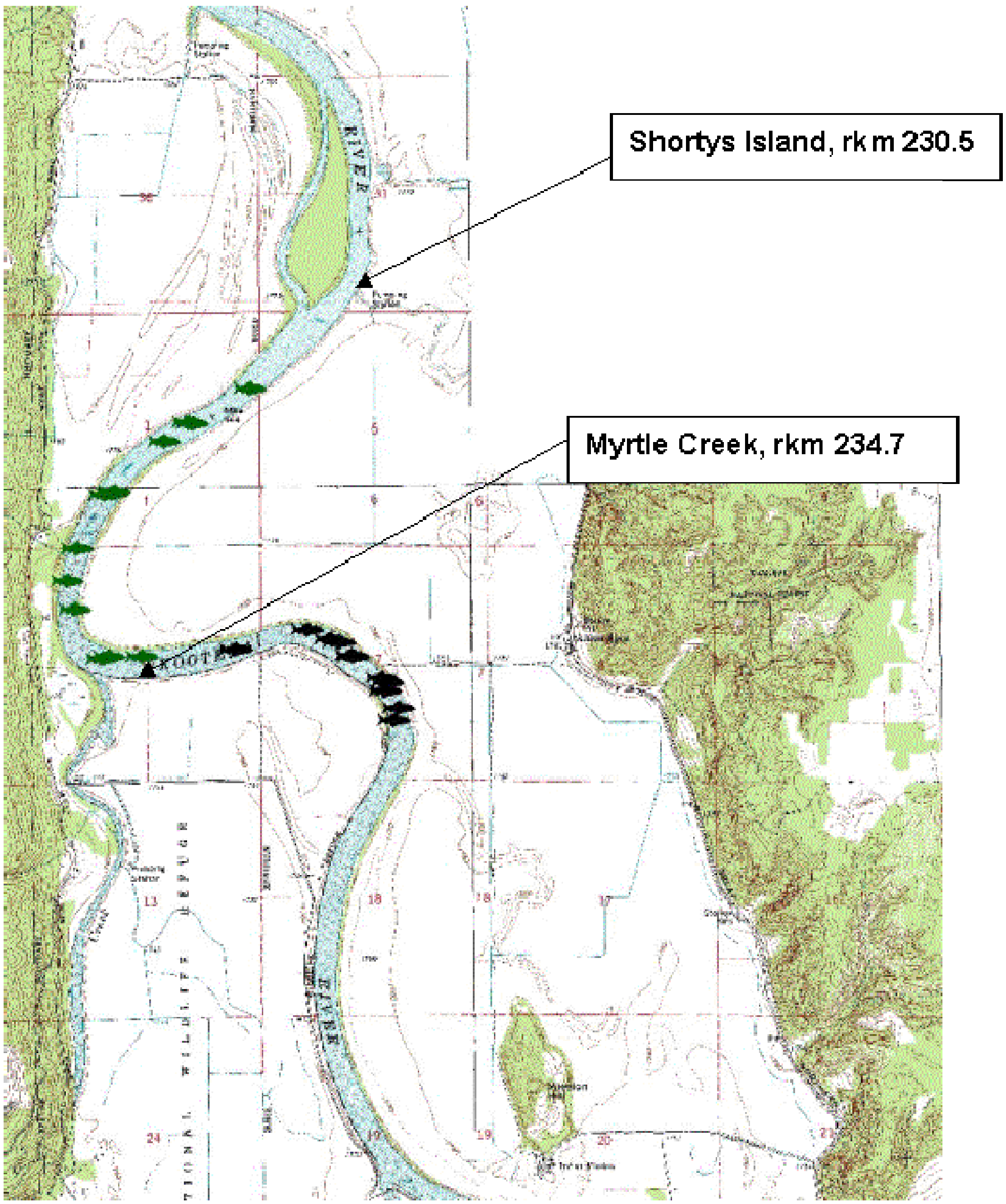
Virtually no movement



Appendix M. Study area and telemetry locations for white sturgeon depth sensitive radio telemetry and behavior studies June 13 and June 15, 2002, Kootenai River, Idaho. Fish symbols with different colors signify different sampling dates. The number of fish symbols of each color signifies the number of times the fish was located each day.

June 13 and 15

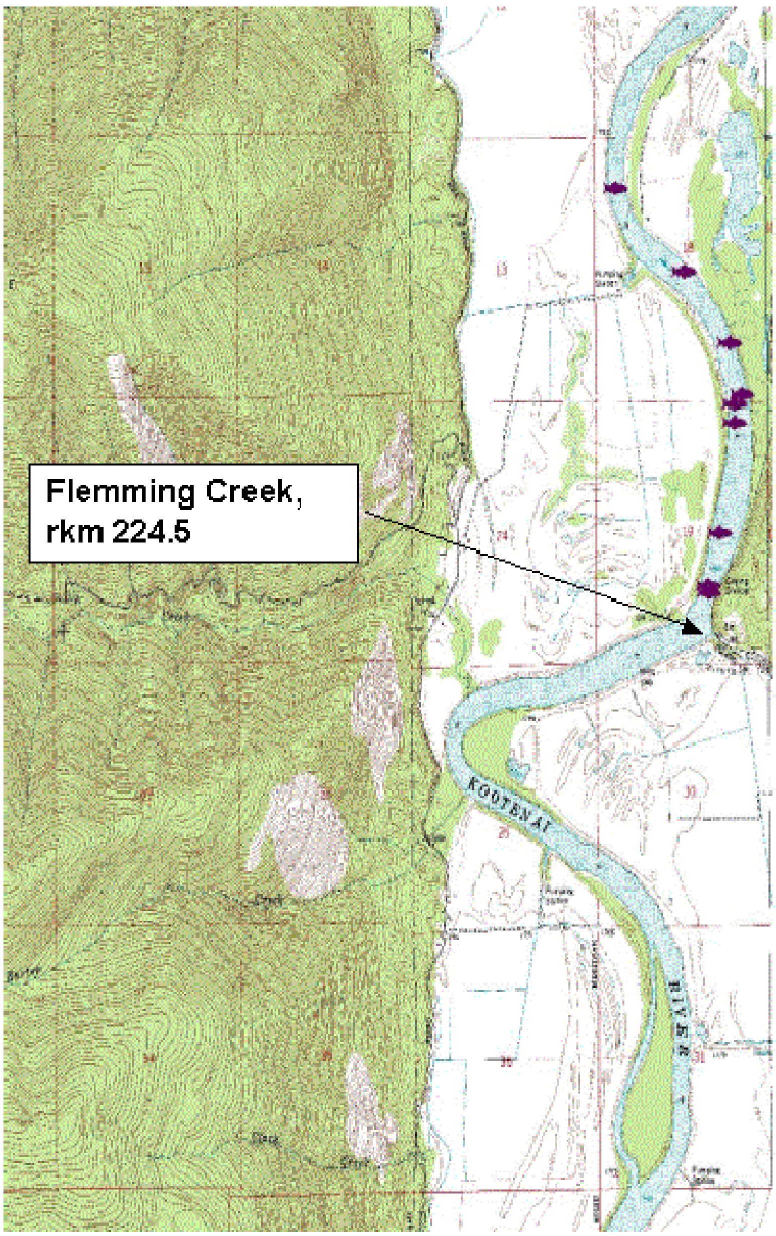
Small erratic movements above Myrtle creek down to Shortys Island.



Appendix N. Study area and telemetry locations for white sturgeon depth sensitive radio telemetry and behavior studies June 17, 2002, Kootenai River, Idaho. Fish symbols with different colors signify different sampling dates. The number of fish symbols of each color signifies the number of times the fish was located each day.

June 17, fish moving steadily downstream below Flemming Creek

Lost for a week, found two weeks later in Kootenay Lake



Appendix O. River location (RKM), number of eggs, depth (m) and velocity (m/s) at sites where white sturgeon eggs were collected in the Kootenai River, Idaho, 2002.

River section (RKM)	Number of eggs collected	Number of mats w/ eggs	Depth range (m)	Mean depth (m)	0.2[a] Velocity (m/s)	0.8[b] Velocity (m/s)	Mean velocity (m/s)
229.6-231.5	113[c]	7	3.7-20.7	9.5	0.38	0.38	0.38
234.8-237.5	4[d]	3	3.1-18.3	8.9	0.37	0.28	0.33
244.7-246.6	22[e]	4	0.6-7.6	3.7	0.94	0.89	0.91
All locations	139	14	0.6-21.6	8.3	0.54	0.5	0.52

[a] 0.2 of total depth
[b] 0.8 of total depth
[c] Includes 53 dead/damaged eggs
[d] Includes 4 dead eggs
[e] Includes 2 dead eggs

Appendix P. Numbers and recapture rates of hatchery produced white sturgeon juveniles (progeny of wild brood stock) released into the Kootenai River in Idaho and Montana between 1992 and 2002 (from Kootenai Tribe of Idaho and Idaho Department of Fish and Game Annual Reports 1992-2001).

Year class	Number released	Mean total length (mm) at release (S.D.)	Mean weight (g) at release (S.D.)	Release year	Percent (#) recaptured
1990	14	455	321	Summer 1992	0.5%(8)
1991	200	255.0 (17.2)	65.9 (12.8)	Summer 1992	6.2%(97)
1992	91	482.6 (113.0)	549.3 (482.9)	Fall 1994	6.3%(98)
1995	—	—	—	?[a]	0.1%(2)
1995	1,076	228.5 (27.0)	47.3 (16.6)	Spring 1997	23.1%(362)
1995	891	343.7 (43.7)	147.7 (64.0)	Fall 1997	23.2%(363)
1995	99	410.4 (67.9)	287.4 (137.8)	Summer 1998	3.3%(52)
1995	25	581.5 (40.5)	863.3 (197.9)	Summer 1999	0.7%(11)
1995	—	—	—	?[a]	0.6%(9)
1998	306	261 (42.0)	79.5 (44.4)	Fall 1999	1.9%(29)
1999	—	—	—	?[a]	0.1%2)
1999	2,186	251.1(29.6)	70.5 (18.1)	Fall 2000	14.5%(227)
1999	2,074	284.3(54.4)	107.6 (60.1)	Spring 2001	15.5%(243)
2000	3,940	244.0 (38.9)	64.2 (31.0)	Fall 2001	3.0%(47)
2000	2,209	283.1(28.7)	99.3(30.2)	Spring 2002	0.1%(1)
2000	30	365.4(14.0)	195.3(19.9)	Summer 2002	— (0)
2000	214	409.4(53.5)	294.1(109.8)	Fall 2002	— (0)
2001	7,141	217.2(32.8)	44.6(18.6)	Fall 2002	— (0)
?[b]	—	—	—	—	0.8%(13)
Total	20,496	—	—	NA	7.6%(1,564)

[a] Year class determined by scute removal; PIT tag not matched in database to determine stock year.
[b] These juvenile white sturgeon had no PIT tag; year class could not be determined by scute removals.

Appendix Q. Year class, number captured, capture locations, fork length (cm), total length (cm), and weight (kg) of hatchery released juvenile sturgeon captured with gillnets from the Kootenai River, Idaho 2002.

Year class	Number captured	Capture RKM	Fork length (cm)	Total length (cm)	Weight (Kg)
1990	1	205.0	73.9	87.6	2.7
1991	3	121.0	67-76.5	77.2-92	2.1-3.85
	2	205.0	54.6-71	64.5-83	1.05-2.25
	2	215.5	70.5-74	81-84.6	2.08-2.1
1992	1	121.0	77	92	3.19
	1	161.0	67.3	77.5	2.1
	4	205.0	62-64.5	70.3-75.7	1.27-1.68
	1	208.0	70.4	79.4	1.9
	3	215.5	60-72.5	69.2-83.5	1.08-2.13
1995	1	119.0	58	67.1	1.27
	8	121.0	43.9-74	50-85.5	0.6-2.2
	1	130.0	38	43.9	0.46
	1	134.0	61.3	70.5	1.28
	1	137.0	50.9	59.2	0.76
	3	145.0	42.5-59.5	50-68.9	0.5-1.25
	1	157.0	54.1	62.6	0.99
	1	161.0	45.6	51.8	0.44
	1	163.0	49.1	56.9	0.73
	40	205.0	38-59.1	44.1-68.3	0.49-1.36
	2	205.5	45.7-49.4	53-57.1	0.618-0.73
	33	215.5	38.9-56	44.1-64.2	0.35-1.05
	7	225.0	45.3-56	53-65.1	0.52-1.1
	2	227.8	48.3-51.5	54.8-60.2	0.65-0.78
	1	234.5	52	60.2	0.83
1998	3	205.0	32.5-41.5	37.2-47.5	0.2-0.42
	2	215.5	29-31	36.4-45.4	0.164-0.34
	1	225.0	31.3	36.1	0.2
	1	227.8	28.4	33.1	0.13
1999	16	121.0	29.5-40	34-47.1	0.17-0.36
	1	123.0	32.3	37.5	0.22
	4	130.0	27.6-38	31.8-44	0.12-0.34
	4	134.0	31.3-33.5	36.5-39.3	0.17-0.26
	5	145.0	26.5-35.5	31.1-41.1	0.11-0.29
	1	157.0	32.8	37.9	0.19
	9	161.0	27.4-33.1	31.9-39	0.13-0.21
	1	163.0	29	34.3	0.13
	2	165.0	28.8-29.3	33.6-34.6	0.14-0.15
	6	190.3	27-41.5	31.1-49.1	0.11-0.36
	3	192.0	28.5-30.5	33-35	0.15-0.17
	63	205.0	27.5-39.3	31.9-45.3	0.05-0.35
	12	205.5	25.6-36.4	29.1-42.5	0.11-0.25
	7	208.0	27.1-35.1	31.4-41.5	0.112-0.23
	33	215.5	20.9-40.8	33.6-48	0.14-0.36
	2	225.0	30.3-33.3	35.1-39	0.14-0.2
	1	?	27.3	31.5	0.14
2000	1	121.0	26.4	30.4	0.12
	1	157.0	26.5	30.8	0.09
	2	161.0	21.8-29.3	24.5-34.2	0.07-0.17
	2	190.3	25.5-29	30.9-33.6	0.09-0.14
	2	192.0	30	35	0.14-0.16
	22	205.0	21-32.5	26.2-37.9	0.05-1.1
	6	205.5	24.1-31	28-35.7	0.08-0.14
	2	208.0	25.6-32	30-37.5	0.10-0.19
	7	215.5	25.1-32.5	27.3-37.5	0.09-0.3
	1	225.0	29.6	34.1	0.15
	1	227.8	24.3	27.8	0.09

Prepared by:

Pete Rust
Senior Fisheries Research Biologist

Vaughn L. Paragamian
Principal Fisheries Research Biologist

Virginia Wakkinen
Senior Fisheries Technician

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Virgil K. Moore, Chief
Bureau of Fisheries

Daniel J. Schill
Fisheries Research Manager